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HOW WE KNOW  
WHAT DINOSAURS  
LOOKED LIKE

## DAWN OF THE GM BABY

**Can we beat disease  
before we're born?**

**PLUS**

## 2016 Preview

Universal internet  
**Jupiter flyby**  
The lynx returns

**DISCOVER**

- How bright daylight is on Pluto
- What makes the ocean salty
- Why paper cuts hurt so much



### FORMULA DRONE

A new sport  
takes off

**+** IS IT THE END  
FOR DIESEL?

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# WELCOME



THIS YEAR, TWO parents will welcome the first genetically modified baby into the world. This newborn will inherit DNA from three people: their parents and a donor, whose DNA will fix a fault in their genes. This small modification will stop the child from inheriting a disease that would slowly rob them of the ability to walk, talk and eat.

At first, this treatment will only benefit a small number of children, but some believe it could open a door to a new approach to medicine that will stop disease before it ever takes hold. This idea has its critics. Some think harnessing DNA in this way risks unforeseen consequences down the line. Make up your own mind on p36.

In another first, *Focus* went drone racing. It was a contest of cutting-edge technology, smart engineering and fast reflexes that was hard not to love. Turn to p42 to find out what we learned.

January in the UK is one of the most miserable months of the year. It feels like a barrage of endless nights, sub-zero temperatures and treacherous roads. But wouldn't it be nice if we took inspiration from Mother Nature and just hibernated? Turn to p90 to discover all the gadgets you need to survive winter without ever setting foot outside your front door.

*Daniel Bennett*

Daniel Bennett, Acting Editor

**PS Don't miss our February issue, on sale 4 February 2016**



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## THIS MONTH WE...



**...attended the launch of the 'data dome' at At-Bristol**, part of the Bristol is Open network. The dome, which is also At-Bristol's planetarium, is the highest-resolution video screen in Europe.

**...checked out the new infotainment system for Jaguar and Land Rover cars**, which features a laser heads-up display on the windscreen and turns your car into a Wi-Fi hotspot.



**...finally got our hands on a Samsung Gear VR headset**. Look out for a full report on what promises to be a landmark piece of VR kit in a forthcoming issue of *BBC Focus*.

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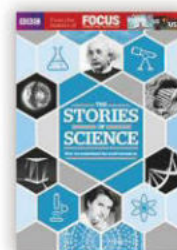
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## APPEARING IN THIS ISSUE...



### Stuart Clark

Stuart takes us on a tour of the icy moons in the outer Solar System and wonders whether they may host undiscovered life forms. Find out more on p50.



### Simon Dale

Simon is one of the people responsible for bringing first-person-view drone racing to the UK. Starting on p42 you can find out exactly what this new sport involves.



### Catherine Offord

Catherine took time out of her PhD on the collective behaviour of social insects to take a closer look at some of the entries for the Nikon Small World competition. Join her on p48.



### Shamima Rahman

Shamima is a professor at UCL and has spent 20 years working with mitochondrial diseases. She provided her expertise on three-parent babies on p36.



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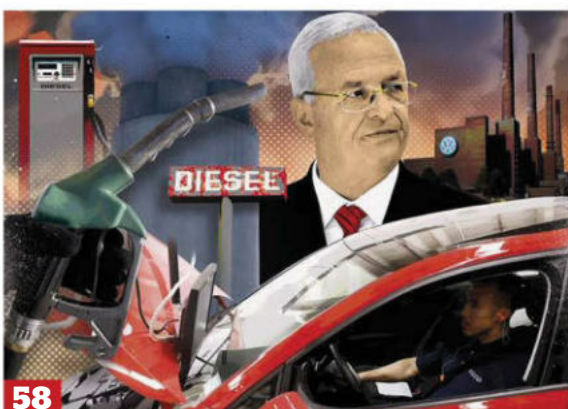
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Awe-inspiring images from the world of science

# MegaPixel

## Operating theatre

SURGEONS RACE TO perform a delicate heart-lung bypass operation but no lives are at stake: the 'baby' seen here is a medical simulator designed to allow doctors to rehearse difficult or complex medical procedures.

The simulator is the result of a collaboration between Boston Children's Hospital's SIMPeds (simulated paediatrics) programme and Emmy Award-winning special effects company Fractured FX.

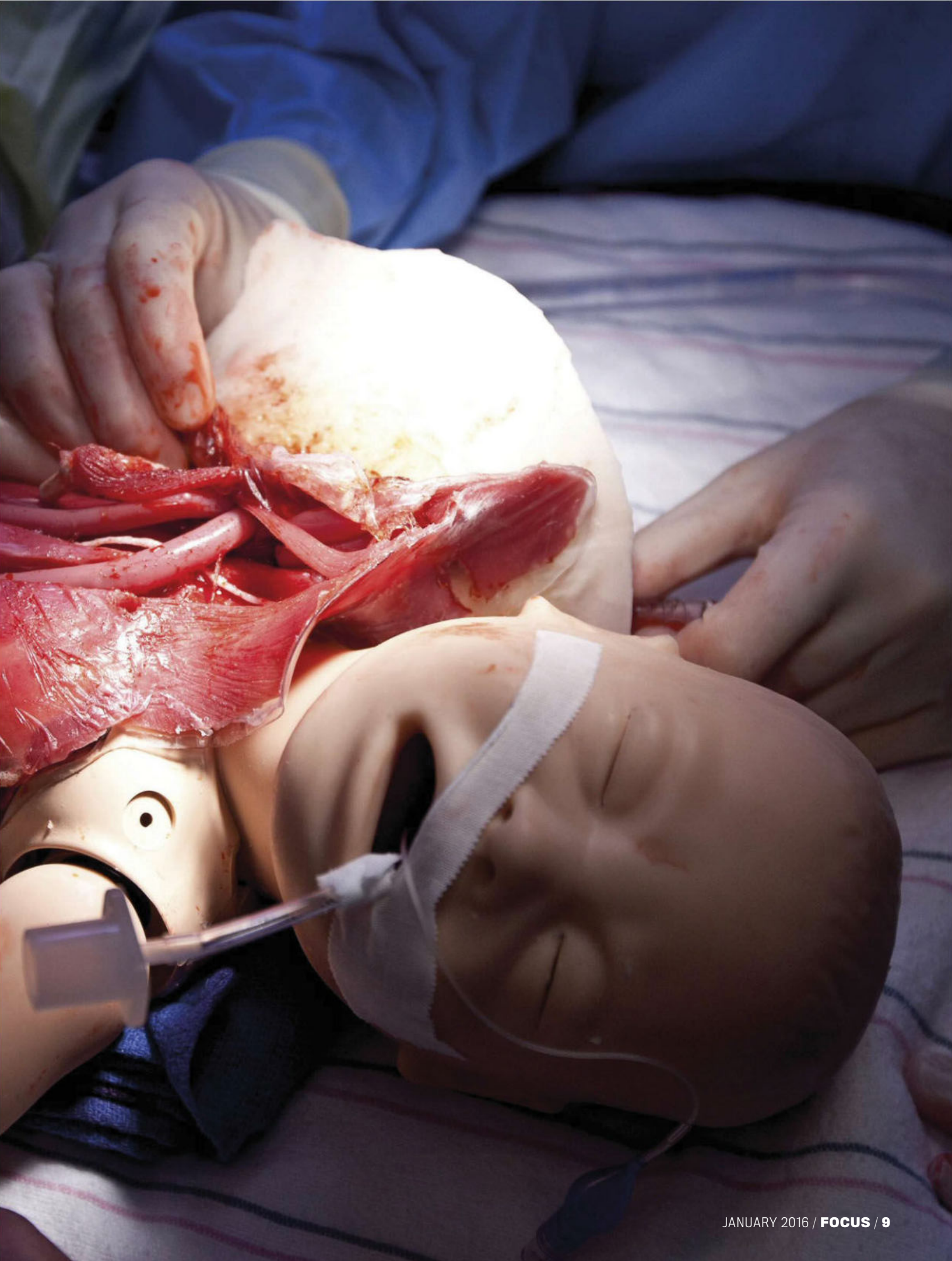
The partnership began when SIMPeds' director Peter Weinstock contacted Fractured FX after being impressed with the realism of their work on *The Knick*, a TV series set in a New York City hospital in the early 1900s.

The simulator models feature artificial skin, fat, muscle and brain tissue that closely resemble the real thing and bleed and pulsate as if they're alive.

"Getting the look and feel right is very important, particularly to surgeons," says Weinstock. "To make simulations effective, you want to promote suspension of disbelief, to create an environment where everyone believes that they're working on a real child. Other simulators exist but their aesthetics and anatomy are fairly rudimentary, which makes it harder to keep people's heads in the game."

PHOTO: EYEVINE









MegaPixel

## Firewater

THE SLOW-MOVING waters of Devil's Ear Spring in northern Florida are ablaze with colour. The vibrant swirls are created when fresh water rising from the spring mixes with the tannin-stained waters of the Santa Fe River.

The tannins are released into the river from decaying vegetation further upstream and stain the water a reddish brown colour. As a result, rivers such as the Santa Fe are classed as blackwater rivers.

Tannins are found in many species of plant, and the bitter taste they impart is thought to deter insects from feeding on the foliage.

PHOTO: JOHN MORAN









MegaPixel

## Psychedelic storm

LIGHTNING CRASHES AMID the smoke and ash rising from the Halema'uma'u Crater in Hawaii Volcanoes National Park.

Located within the summit caldera of Kilauea, the crater measures 770 x 900m across and is sunk 83m into the ground. It's currently volcanically active and houses a lake of bubbling molten lava.

The picture shows a rare atmospheric phenomenon

called volcanic lightning, also known as a 'dirty thunderstorm', which occurs when static electrical charges are generated by the collisions of rock and ash in the volcanic plume. In a regular thunderstorm it is the collisions between ice crystals in the atmosphere that produce the charges that cause lightning.

PHOTO: JOHN MIKAN/CATERS NEWS





# REPLY

Your opinions on science, technology and *BBC Focus Magazine*



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Letters may be edited for publication

## MESSAGE OF THE MONTH



Will we ever revive the mammoth, or is it just a shaggy elephant story?

## A mammoth undertaking

EVER SINCE I was a little boy my father would tell me tales of mammoths grazing the British Isles, being hunted by man and driven to extinction. Whether or not the theories of overhunting are true, it was the perfect parable for a child, demonstrating just how reckless the human race can be. I grew up with a deep understanding of the fragility of our planet and the creatures which inhabit it, and I believe it made me a better person.

But to coincide with these fables, he would keep me informed about the de-extinction efforts and constantly reiterated that, one day, I might actually see a living mammoth for myself! And it seems like the dream is getting closer and closer to becoming a reality. The recent mapping of a complete woolly mammoth genome has re-sparked my interest in species revivalism.

There are apparently three projects underway which are attempting to create a mammoth-elephant hybrid, and many others focused on other extinct animals. With new advancements, perhaps now would be a fitting time to publish a feature on the subject?

**Adam Manuel**

*We'll see what we can dig up. – Ed*

## Write in and win!

The writer of next issue's Message of the Month wins an Energenie MiHome Starter Kit worth £69.99. The MiHome range of 'smart' plugs and switches give you Internet of Things-like control over your existing appliances via your smartphone and the MiHome Gateway. For more info, see [energenie4u.co.uk](http://energenie4u.co.uk)



## Bedside manner

I enjoyed reading the December issue of *Focus*, but one part of it caught my attention – the part about how robots will one day free us from the 9 to 5 ('The end of work?', p53).

Although I agree with the article in some aspects, one example is robots taking over car-making as there are only so many people who would be willing to rivet a part for eight hours, I had a rather strong disagreement with the part later on where it suggests that there will be robot doctors.

I feel that people are more likely to prefer a human doctor, as they have years of training instead of days or weeks of programming, and the skill of empathy, which a robot wouldn't be capable of. Yes, a robot might prove quicker and better at diagnosing, but I think that people are more likely to open up to a human doctor. It is, perhaps, in our nature to be more comfortable with the familiar, and to reject the strange and the new.

Another argument against robot doctors is 'the uncanny valley,' where something looks almost human but is just different enough to be considered creepy. I myself fell victim to this on p53, where one of the robot's eyes seemed slightly 'off'.

Until mankind is capable of perfecting the looks of robots, I think people are likely to avoid the uncanny valley and instead go for the more comforting, human approach to medicine.

**Toby Carter, Gloucestershire**

## In a spin

In your November issue, the article about building a base on the Moon (p60) contains two statements that seem to contradict each other. The author mentions "the far side of the Moon – the face that always points away from the Earth," implying there is no rotation. He later says, "taking nearly a month to complete one rotation on its axis," implying that the Moon *does* rotate.

I'm sure other readers would also like further clarification here.

**Krishnan Sriram, Chicago, USA**



*This is a common source of confusion. Yes, I said the same side always faces away from the Earth – it does. But it is wrong to assume this means no rotation. The Moon orbits around the Earth in exactly the same time as it takes for it to rotate on its own axis, so we always see the same face.*

– **Colin Stuart**

## Seasons and CO<sub>2</sub>

In the December issue article on global warming ('How do we know?', p106) you mention Charles Keeling, who found that carbon dioxide levels dipped every summer, and concluded that the variation was therefore seasonal. However, the two hemispheres of Earth have opposite seasons – summer in the north means winter in the south. Should they therefore not balance each other out?

The rise and fall of CO<sub>2</sub> may well be seasonal, but it must apply inversely to each hemisphere.

**David Batty, Felixstowe**

*Thanks for your question. It's an interesting one, but there are two main reasons why seasonal cycles in atmospheric carbon dioxide don't get balanced out by the differences between the north and south hemispheres.*

*Firstly, the southern hemisphere is dominated by ocean, whereas in the northern hemisphere there is more land, and so seasonal shifts in atmospheric carbon dioxide are dominated by the northern hemisphere's seasonal cycle of microbes, plants and trees. This means that CO<sub>2</sub> reaches a peak in May, and then drops through the summer, as trees come into leaf and photosynthesis draws down CO<sub>2</sub>.*



*Secondly, it takes roughly a year for air to mix between the northern and southern hemispheres, whereas air only takes a few weeks to mix within a hemisphere. So even if the southern hemisphere did have more land, carbon dioxide measurements at Mauna Loa would still be dominated by the northern hemisphere's seasonal cycle.*

– **Kate Ravilious**

## A meaty question

I was a little disappointed to read the article about climate change (November, p60) and find nothing about agriculture, which is a far more significant driver of climate change than energy, industry and transport combined. I often hear people complaining about refugees, and my reply is to put down the cheeseburger! Climate change = drought = poverty = civil unrest = refugees. Each cheeseburger uses as much fresh water as showering for two months, never mind methane emissions and cutting down nature for grazing.

Meat is fine – but in moderation, not consumed to the excessive levels we enjoy (and then become upset that cancer rates are rising from eating it).

**Adam Shaw**



Eating fewer of these will help combat climate change, says Adam Shaw

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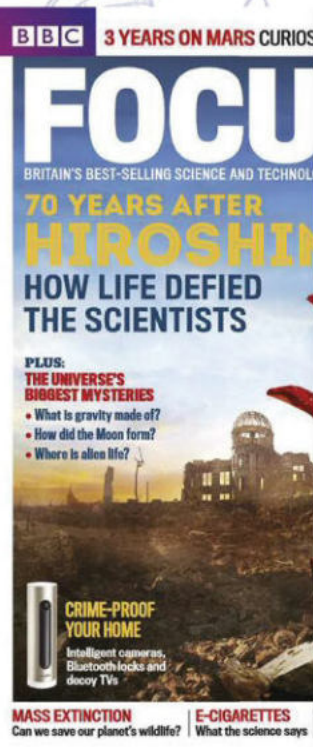
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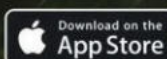
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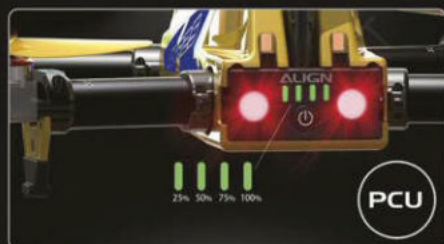
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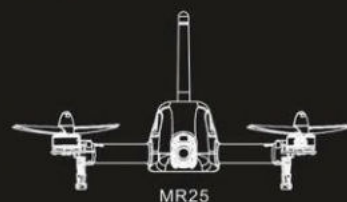
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News and views from the world of science

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Why the Isle of Skye was the place to be in the mid-Jurassic

p26



## GROW YOUR OWN PC

Researchers in Sweden embed transistors inside a living rose

### THE BIG STORY

## \$2.5 MILLION EXPERIMENT FINDS **NO EVIDENCE THE UNIVERSE IS A HOLOGRAM**

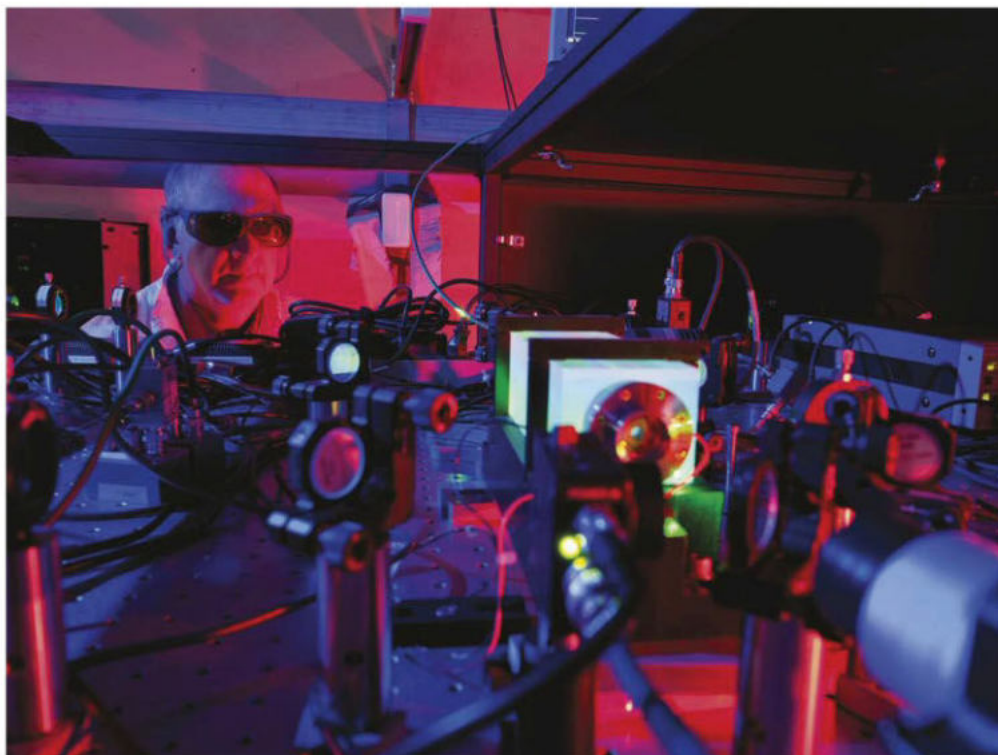
One of the most bizarre-sounding ideas in theoretical physics has suffered a significant blow. After a year of taking painstakingly precise measurements, Fermilab's Holometer experiment has found no evidence to back up the theory that we are living in a hologram...



After two decades, the holographic principle has suffered a bit of a setback

PHOTO: ISTOCK





The laser interferometer at the centre of the Holometer experiment

**FIRST PROPOSED** BY Gerard 't Hooft in 1993 and refined by others since, the holographic theory says that rather than being continuous, space and time come in tiny, indivisible amounts, in much the same way as the energy levels on the atomic scale do in quantum physics. This has been likened to the Universe being akin to a 2D TV screen. We perceive the world shown on-screen in 3D, but in reality it exists as 3D information encoded on a 2D space. It's essentially the same principle used by holograms, such as those found on credit cards.

Carl Hogan of Fermilab, one of the scientists who's pursued 't Hooft's ideas, suggests that if you zoom into the 'screen' enough you should see tiny 'pixels' of information. He's been searching for these telltale signs using Fermilab's Holometer, which uses a pair of lasers to detect minute fluctuations, or jitters, in the fabric of space-time itself. So far, the experiment has measured movements lasting just a

millionth of a second and distances that are a billionth of a billionth of a metre – 1,000 times smaller than a single proton. It has not detected the holographic noise or quantum jitter that Hogan's theory predicts, so either it needs to look in even finer detail or the theory is wrong.

"This is just the beginning of the story," said Hogan. "We've developed a new way of studying space and time that we didn't have before. We weren't even sure we could attain the sensitivity we did."

Hogan says the team will continue to collect and analyse data, and carry out more sensitive studies of holographic noise. In the meantime, they are also working on an updated model of the Universe's holographic structure.

"This is new technology, and the Holometer is just the first example of a new way of studying exotic correlations," Hogan said. "It is just the first glimpse through a newly invented microscope."

## TIMELINE

### A history of the holographic principle

1993

Dutch theoretical physicist Gerard 't Hooft proposes that the Universe could consist of 3D information encoded in 2D space.

1994

Stanford University's Leonard Susskind formulates a new interpretation of 't Hooft's holographic universe principle using string theory.

1997

Juan Maldacena of Princeton University (pictured right) shows that microscopic packets of information are stored at the event horizon of a black hole.



2013

Construction is completed at Fermilab's Holometer, a laser device designed to look for experimental evidence of a holographic universe.

## GOOD MONTH/ BAD MONTH

### It's been good for:

#### ODONTOPHOBES

IF THE SOUND of the dentist's drill literally sets your teeth on edge, read on. A team at the University of Sydney has discovered that the need for fillings can be reduced by up to 50 per cent by using a 'fluoride varnish', monitoring your teeth regularly and brushing correctly. Look out for your teeth and you can dodge the drill!

#### THE QUICK-WITTED

THOSE WHO CAN think on their feet are perceived as more charismatic than their slower counterparts, researchers at the University of Queensland have found. The effect is seen even if the answers given by the quick thinkers are incorrect.



### It's been bad for:

#### TALL PEOPLE

BEING LANKY MEANS you always get a good view in the cinema, but it may also give you a shorter lifespan. A study at the University of Glasgow carried out on sparrows has found changes in DNA linked to ageing take place as body size increases. The effect is due to the greater number of times cells must divide to grow bigger and taller, the researchers say.

#### HEDGEHOGS

NUMBERS OF BRITISH hedgehogs have fallen by one-third in the last decade, the People's Trust for Endangered Species has found. The decline is thought to be down to the popularity of paved and gravel gardens. Making sure your fence has a 13cm square gap could help hedgehogs, by letting them travel around more easily.







## Why scientists need to be collecting dust

**DAVID SHUKMAN**  
The science that matters

**B**ACK IN SCHOOL, many of us were taught about the Gulf Stream, that great river of warm water crossing the Atlantic. But liquid isn't the only state a stream can flow in. Up in the atmosphere, streams of dust carry vast plumes of tiny particles over thousands of miles.

A few years ago people in England were surprised to find their cars covered in dust that had blown from the Sahara desert. Sometimes entire regions of the Middle East are engulfed in storms of dust. And air currents take dust to the oceans where it fertilises plankton.

But dust plays a more fundamental role too: affecting the climate. Clouds of particles can either reflect incoming radiation from the Sun – and therefore cool the planet – or act as a blanket trapping heat closer to the surface, thereby adding to rising temperatures.

With that in mind, the question on a lot of experts' lips is: will global warming make the atmosphere dustier? Scientists have been puzzling over this for years. So a team led by Oxford University travelled to one of the largest sources of dust on the planet, the vast salt pan in Namibia's Etosha National Park, in southwest Africa.

In the ferocious midday heat, with the sunlight glinting on



Could global warming lead to more dust storms like the one that hit the Middle East in September 2015?

the array of instruments, we filmed the researchers collecting their data. They had devices for measuring how much dust is carried at different heights above the ground and for assessing the size of the dust streams leaving the surface.

The surface itself was brittle. With every step I took, my boots

broke through a salty crust, exposing what felt like superfine talcum powder beneath. This superfine dust is what gets picked up by the wind and there's so much of it that it forms plumes large enough to be visible from space.

The results of this study will be fed into computer simulations

of the climate to help improve the projections for future change. None of us likes dust on our hands or on the surfaces in our homes but it's something we need to know more about.

**DAVID SHUKMAN** is the BBC's Science Editor. @davidshukmanbbc

## WHO'S IN THE NEWS?

### Humai

#### Who are they?

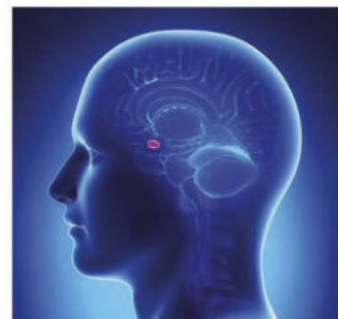
An artificial intelligence company based in Los Angeles that claims to be working on technology to bring the dead back to life. They hope to succeed by 2030.

#### Are they for real?

There's not much to go on other than a website and a few interviews. At this stage it's difficult to say if they're conducting genuine research, or if the whole thing is a hoax or marketing campaign.

#### So how do they plan to introduce resurrection?

They say they are going to use nanotechnology to store data that relates to a person's behaviour, thought processes and bodily functions, and load this into the brain of a deceased human. This brain will then be placed into an artificial body and treated with various therapies to repair the cells.



SPACE

## ESA kicks off the search for gravitational waves

The LISA Pathfinder experiment launched on 3 December 2015, bound for the L1 Lagrange Point

THE EUROPEAN SPACE Agency (ESA) has successfully launched its LISA Pathfinder experiment atop a Vega rocket from a spaceport in Kourou, French Guiana.

The experiment will test a method of detecting gravitational waves, ripples in the fabric of space-time thought to be generated by massive bodies and predicted by General Relativity.

As we went to press, LISA Pathfinder was en route to L1. This is a point 1.5 million kilometres away where the Earth's and the Sun's gravity balance out, allowing the craft to remain in a stable orbit.

After reaching L1 in mid-February, it will release its payload: a pair of 46mm gold-platinum cubes separated by 38cm, which will be isolated from all forces acting on them apart from gravity. A system

of lasers bouncing between the cubes will measure their position to an accuracy of 100,000th of the width of a human hair.

If the mission is a success, it will give the green light to a much larger system potentially capable of detecting the ripples caused by gravitational waves.

"Gravitational waves are the next frontier for astronomers. We've been looking at the Universe in visible light for millennia and across the whole electromagnetic spectrum in just the past century," said Alvaro Giménez Cañete, ESA's Director of Science and Robotic Exploration. "But by testing Einstein's predictions with the LISA Pathfinder, we're paving the road towards a fundamentally new window on the Universe."

**"We're paving the road towards a fundamentally new window on the Universe"**

Alvaro Giménez Cañete, Director of Science and Robotic Exploration, European Space Agency



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## 1 MINUTE EXPERT

### Metformin



**What's that? A new dance craze taking the clubs of New York by storm?**

Don't be silly. It's a drug currently used to treat Type 2 diabetes that may help humans live well into their 110s by slowing down the ageing process.



**Wow. Tell me more.**

Don't get too excited. So far the drug has only been trialled on worms and mice but in both cases it was seen to successfully extend the creatures' lifespans.



**How does it work?**

It's believed that the drug alters the metabolism in bacteria that live in the animals' guts, limiting the nutrients that are available. Researchers think the process maybe similar to the life-extending effects of a low-calorie diet.



**But does it work in humans?**

We don't know yet. A clinical trial named Targeting Aging with Metformin, or TAME, is due to kick off in the US next year.



## BIOLOGY

# 'Dinosaur disco' unearthed in Scotland's Isle of Skye



IF YOU WERE a gigantic herbivorous dinosaur living around 170 million years ago it seems the Isle of Skye was the place to be.

Researchers at the University of Edinburgh have discovered hundreds of footprints made by plant-eating sauropods in the Inner Hebrides. The discovery is the biggest dinosaur site found in Scotland to date.

The tracks were found peppered among layers of rock that would have been at the bottom of a shallow, saltwater lagoon at the time they were made. By analysing the structure of the footprints, the largest of which measures 70cm across, the team believe the dinosaurs were early relatives of the *Brontosaurus* and *Diplodocus* and grew to at least 15 metres in length and weighed more than 10 tonnes.

"The new track site from Skye is one of the most remarkable dinosaur discoveries ever made in Scotland," said lead author Steve Brusatte. "There are

so many tracks crossing each other that it looks like a dinosaur disco preserved in stone. By following the tracks you can walk with these dinosaurs as they waded through a lagoon 170 million years ago, when Scotland was so much warmer than today."

It was previously thought that large dinosaurs were purely land-dwellers. The tracks reveal that sauropods spent lots of time in coastal areas and shallow water.

"This find clearly establishes the Isle of Skye as an area of major importance for research into the mid-Jurassic period," said researcher Tom Challands. "It's exhilarating to make such a discovery and be able to study it in detail. But the best thing of all is that this is only the tip of the iceberg. I'm certain the Isle of Skye will continue to yield great sites and specimens for years to come."



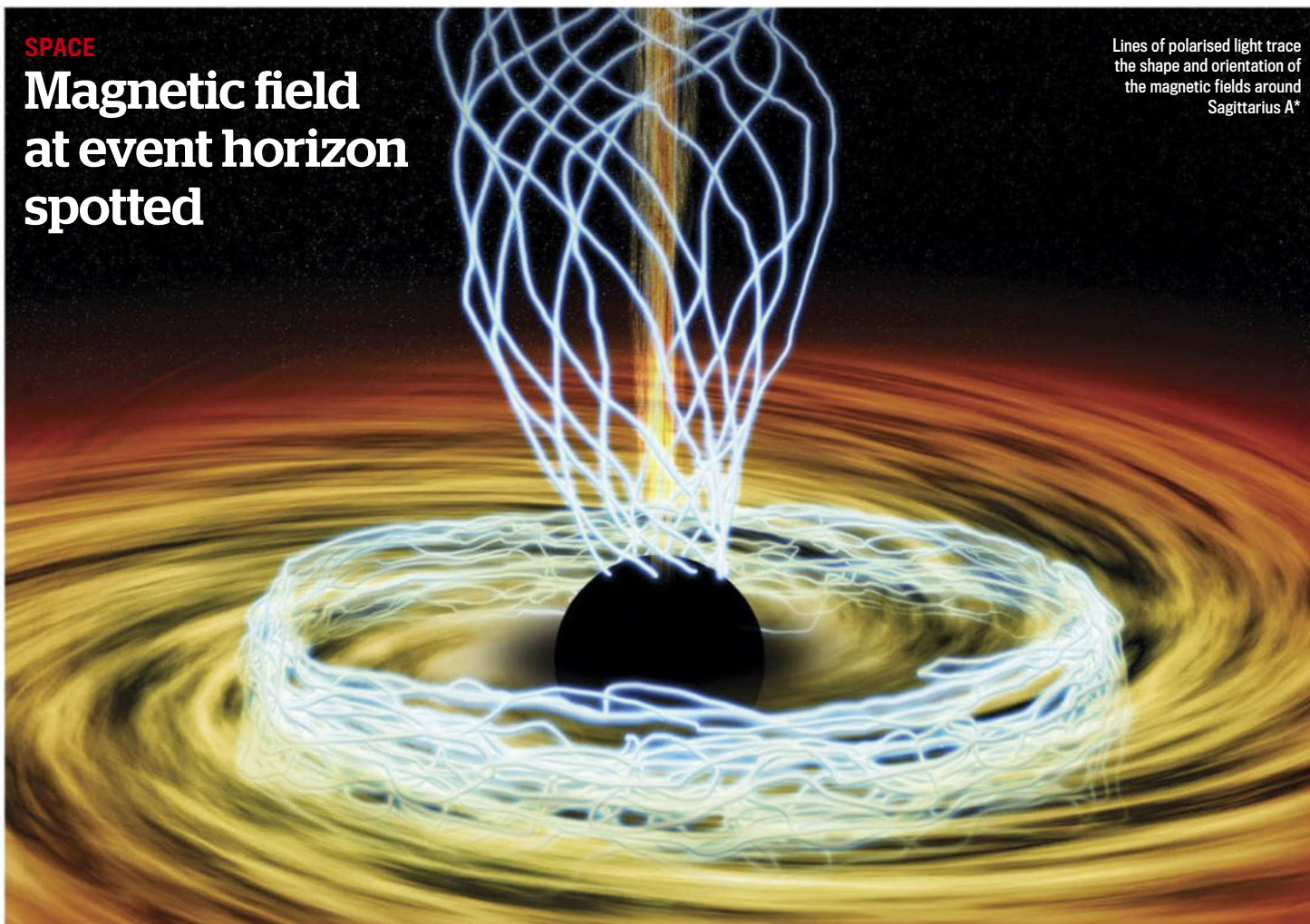
A cast of one of the sauropod footprints found on Skye



## SPACE

# Magnetic field at event horizon spotted

Lines of polarised light trace the shape and orientation of the magnetic fields around Sagittarius A\*



FOR THE FIRST time, astronomers have detected magnetic fields near the event horizon of Sagittarius A\*, the black hole that lies at the centre of our Galaxy.

"These magnetic fields have been predicted to exist, but no one has seen them before. Our data puts decades of theoretical work on solid observational ground," said Principal Investigator Shep Doeleman,

the Assistant Director of MIT's Haystack Observatory.

The presence of the fields was revealed using the Event Horizon Telescope (EHT) – a global network of radio telescopes that function as one giant scope the size of Earth.

The EHT team detected the magnetic fields by measuring the linear polarisation of the light emitted by Sagittarius A\*. The polarised light is emitted

by electrons spiralling around magnetic field lines and so directly traces the structure of the magnetic field.

"With this result, the EHT team is one step closer to solving a central paradox in astronomy: why are black holes so bright [if their gravitational pull is so great they can draw in light]?" said Doeleman.

This groundbreaking observation was made possible

thanks to the remarkable resolution a telescope the size of the EHT offers. It's hoped, however, that more radio dishes from around the world will be added to the EHT's network enabling it to gather even more astronomical data. More data will allow the EHT's astronomers to achieve greater resolution, possibly enough to directly image a black hole's event horizon for the first time.

## THEY DID WHAT?!

### Fitness tracker made from used chewing gum

#### What did they do?

A team at the University of Manitoba embedded a solution

of carbon nanotubes into a piece of chewing gum that had been chewed for 30 minutes and left overnight.

#### Urgh! What did they find?

Believe it or not the strange concoction resulted in a highly sensitive flexible sensor capable of recording movements such as human head turning and finger

bending. It could also detect changes in humidity, potentially making it capable of monitoring changes in breathing.

#### Why did they do that?

They were searching for a flexible material to use as a miniature sensor that could be used in biochips and bodily motion sensors.





# 10 DISCOVERIES THAT WILL SHAPE THE FUTURE

BY GRAHAM SOUTHRN

## 10 DNA motors

THE DREAM OF sending microscopic robots through the body to deliver drugs or repair tissue is a step closer. A DNA motor devised by Emory University chemists moves at the speed of 1cm per week – a vast improvement on previous designs that would have taken 20 years to cover the same distance. It consists of a **glass sphere with hundreds of DNA legs**. The legs bind to RNA on a surface and then detach from the sphere to propel it along. The motor could be used in disease diagnosis or even biological computers.

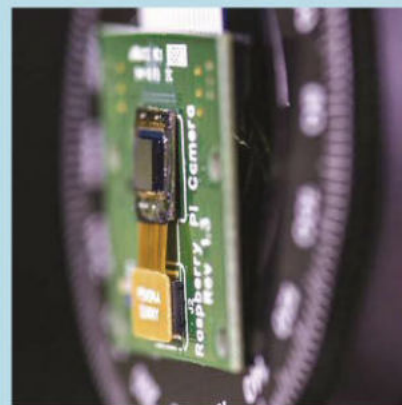


Khalida Salaita and Kevin Yehl (below) helped create a new 'high-speed' DNA motor



## 9 Flat camera

A FLAT CAMERA with no lens could better today's smartphone snappers in low-light conditions. To house lenses, today's cameras are cube-shaped. But Rice University scientists have developed a prototype that's around 1mm thick, enabling it to be built into wallpaper, credit cards and curved surfaces. The FlatCam **has a mask instead of a lens and constructs an image using computer algorithms**. Since they're made like computer chips, the breakthrough could lead to cheap, disposable digital cameras.



New lensless, flat cameras could be built into wallpaper

## 8 Hairy clothing

FUR IS PROBABLY the last material you'd think would be water-repellent, but scientists at MIT have proved otherwise. They found that long, dense hairs help the skin below stay dry by trapping air between them. Also, the trapped air doesn't conduct heat anywhere near as well as water, so it helps semi-aquatic animals like fur seals and otters to stay warm too. The research could lead to **better wetsuits and waterproof clothing**.



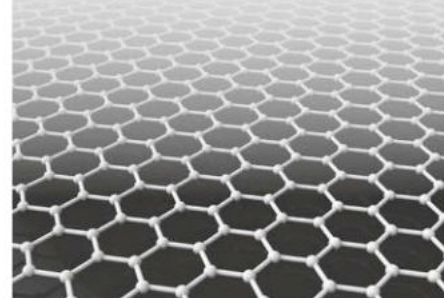
## 7 Seeing round corners



IT'S NOW POSSIBLE to see around corners thanks to a new camera developed at Heriot-Watt University, Edinburgh. The camera **scatters a laser beam in all directions and detects any 'echoes' that hit objects and return to the camera**. Applications include dashboard cameras that show drivers potential hazards around the next bend.

## 6 Graphene microphone

A MICROPHONE WITH a vibrating graphene membrane has been made at the University of Belgrade. It's **32 times more sensitive than current commercial models based on nickel**. Eventually, graphene mics could capture more than just audible frequencies – a membrane with more layers could pick up ultrasonic sound.





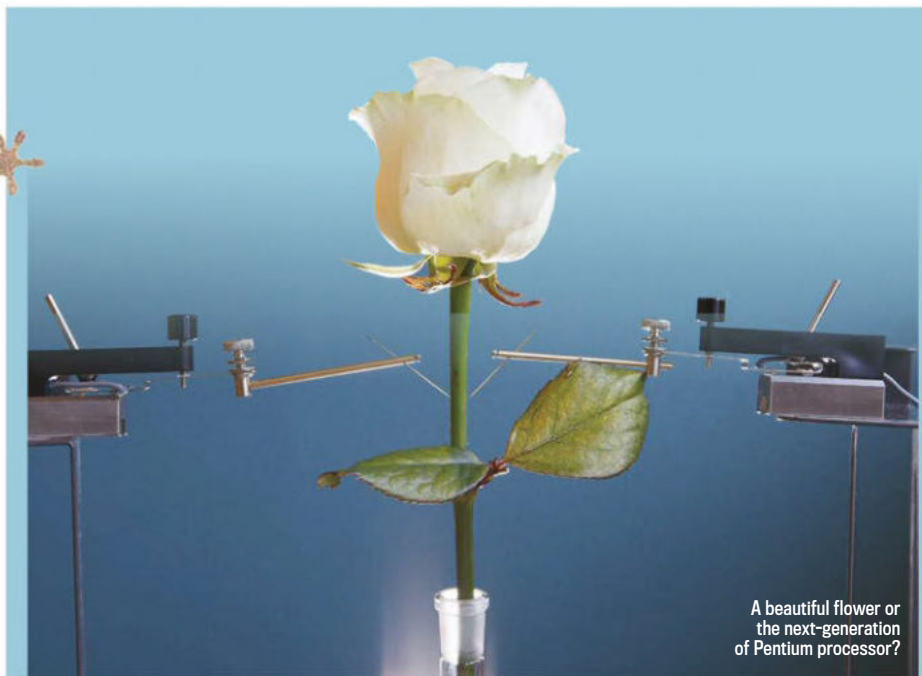
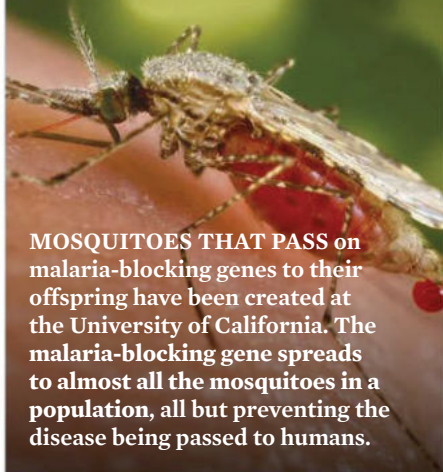
## 5 Gecko glue

SCIENTISTS AT CHINA'S Nantong University have sequenced a gecko genome and found the genes that help it form the fine toe hairs it needs to climb walls. The study may lead to new adhesives and other breakthroughs relating to the gecko's ability to regenerate its tail.



## 4 Malaria-blocking mosquitoes

MOSQUITOES THAT PASS on malaria-blocking genes to their offspring have been created at the University of California. The malaria-blocking gene spreads to almost all the mosquitoes in a population, all but preventing the disease being passed to humans.



A beautiful flower or the next-generation of Pentium processor?

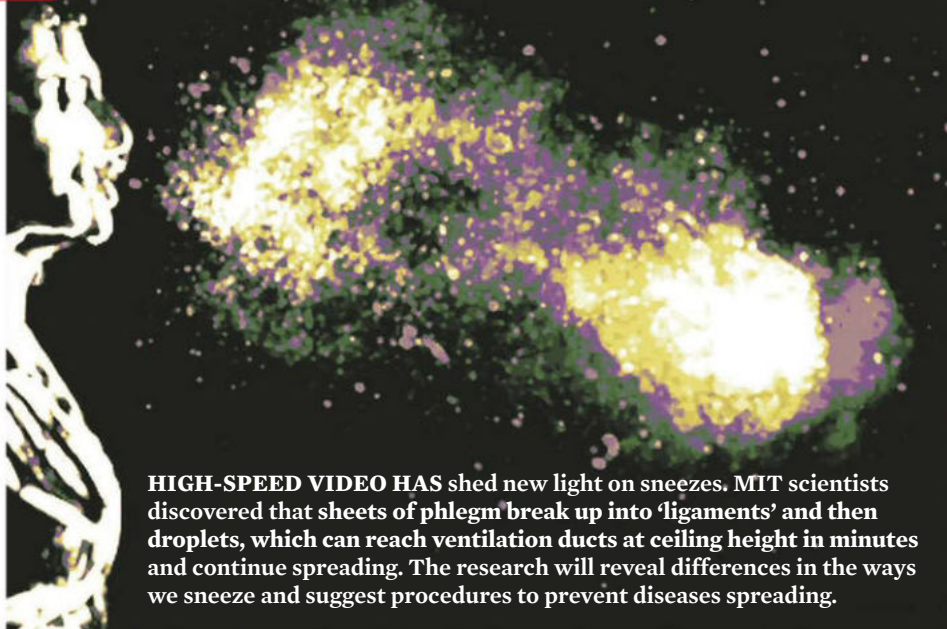
## 3 Electronic plants

COMPUTERS IN YOUR roses and Wi-Fi antennae in your trees are just two of the long-term possibilities presented by organic electronics. At Sweden's Linköping University, scientists embedded a polymer into a rose to

form a working transistor. It's part of a plan to combine electronic circuits with plants' natural signalling mechanisms in the hope of tapping into energy generated by photosynthesis as well as reading and regulating a plant's growth functions.

## 2 Sneezes studied

Scientists at MIT have been studying slow-motion film of sneezes



HIGH-SPEED VIDEO HAS shed new light on sneezes. MIT scientists discovered that sheets of phlegm break up into 'ligaments' and then droplets, which can reach ventilation ducts at ceiling height in minutes and continue spreading. The research will reveal differences in the ways we sneeze and suggest procedures to prevent diseases spreading.

## 1 Robot learners

ROBOTS THAT LEARN from their experiences, just like human infants, are on the horizon. At the University of Washington, computer scientists and psychologists built robots that learn new skills by watching how humans perform tasks. The robots then try various methods to work out how to achieve the same goal.



The new robots learn the same way babies do - by watching



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- Return to home function which brings your drone back to the starting position and hovers 2m above the ground
- Three axis digital stabilisation to keep your video footage nice and steady
- 14 megapixel camera for good quality pictures and high definition video

### What's new with the Bebop 2?

The Bebop 2 has a new battery connection and a rear LED that blinks intermittently during flight to improve visibility. It comes with a new battery for a longer flight time, increased power and speed, better wind resistance, sharper design, improved GPS, better camera angle and the camera is polarised for improved recording when transitioning from low light to bright light. Overall the Bebop 2 has been tweaked to give you a great flying experience. Also available in the all new white A93UF.

### Special Features

- On-board 8GB memory and microSD card slot for additional storage.

### How easy is this drone to fly?

The Bebop drone 2 is an improvement on one of the easiest drones on the market to fly. Using the downloadable FreeFlight 3 app it is fully controllable up to 300m in the air, and you can record to the internal memory and onto a microSD card if you require more space. If you lose sight of your drone, you can press the return to home button and the drone will return to the starting position.

### How does the return to home function work?

When you press the return to home button on the app, your drone will fly back to the starting position using GPS, at a minimum height of 10m. It will continue to hover at 2m until you land it. This function is perfect if you have lost sight of the drone and wish to retrieve it.

### What sort of performance will I see from this drone?

This drone has a maximum speed of 16.6m/s which is the equivalent of 37mph. The now single 2700mAh LiPo battery gives you a maximum flight time of 25 minutes and will ensure you have enough time to have fun and get some great action shots.



UK Drone Store also have the full range of Parrot Mini Drones as seen on 'The Gadget Show' also available at [www.ukdronestore.com](http://www.ukdronestore.com)





**ROBERT MATTHEWS**

# THE INTERNET OF (BAD) THINGS

The next web revolution could create a hacker's heaven

**W**HEN YOU WANT to insult someone in tech-speak, all you have to do is use the L-word: 'Luddite'. Everyone knows what it means: a stupid stick-in-the-mud who can't handle the wonders of technology.

At least, that's what many people think. Its true meaning lies in events in the early 19th Century, when textile workers – supposedly led by one Ned Ludd – revolted against new weaving technology that made thousands redundant, in some cases with devastating consequences.

So Luddites are actually people who are concerned that technology is being foisted on them by big business regardless of the consequences. In which case, I'm a card-carrying Luddite when it comes to the so-called Internet of Things (IoT).

Don't be fooled by the boring-sounding name: the IoT really is a revolution in the making. We all know how the internet has transformed society. The IoT is an even bigger deal: a global network of interconnected devices, able to exchange data with each other. Everything from TVs to lights to cars to... well, you name it.

So soon your car will drive you to your destination, find the best parking spot, tell your house when you're returning home, get the heating and dinner on, while your wristband monitor tells your TV what mood you're in and fixes the night's entertainment. Can't wait for the arrival of this tech-nirvana – or left cold by it? It makes no difference: it's coming your way.

You probably have some 'IoT-ready' technology in your home already.

That's because tech companies can't wait to 'optimise your experience' – that is, collect a tonne of data about you and then sell it on to energy utilities, health insurers and any other 'interested parties'. Frankly, I'd rather put the central heating on myself than have that lot knowing more about me. But that's not my biggest concern about the IoT. Relatively speaking, they're the good guys. What bothers me is that in the race to roll out this tech, too little is being done to keep out the bad guys.

Forget the wide-eyed space cadet stuff about the IoT; the truth is that most of the underlying technology is scarily primitive. And with time, the IoT will no doubt become the target of choice among hackers, spooks and terrorists. Security experts are warning that the IoT already links together hundreds of millions of devices whose vulnerabilities cannot be patched.

**"What bothers me is that in the race to roll out this tech, too little is being done to keep out the bad guys"**



The Internet of Things brings with it a raft of new security concerns

The resulting threat isn't theoretical, either: one tech company recently exposed this by using the IoT to hijack baby monitors, spy remotely and take control of home computers. Meanwhile, the IoT grows ever larger: industry estimates suggest that within five years it will have connected up 10 times more devices than there are humans on Earth.

It's all happening far too fast for governments. By the time they agree to global risk standards, we'll all be caught up in this web. So what can we do? I believe that our best hope lies in the good old-fashioned internet. We can use this to detect and alert each other to all the dodgy devices that threaten our safety and privacy – and get the companies who make them named, shamed and sued. In short, we need to flip the threat from the IoT around, and make sure big businesses know we are keeping tabs on them.

The Luddites lost their fight because they lacked the power to make

profiteering fat cats take their concerns seriously. Two centuries on, we have that power literally at our fingertips. We need to use it, as very soon we may just lose it. ■

**ROBERT MATTHEWS is Visiting Professor in Science at Aston University, Birmingham**





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HELEN CZERSKI

# HELMET HAIR

Why a spot of rain turns you into a frizzball

**W**HILE CYCLING, I don't really mind being rained on. But I do mind arriving at my destination looking like a drowned rat. This week, I've been caught by showers during my commute on three separate days. I've got towels at work to dry off, and I can always change my clothes, but my hair gives the game away every time. My cycling helmet is full of ventilation holes and is basically useless as an umbrella. And so I arrive with my hair plastered down flat and weirdly frizzy. As I felt the first heavy drops of rain on the third occasion this week, I found myself wondering why hair changes shape so easily. It's just strands of protein. Why does getting it wet make such a difference?

Hair is simultaneously very strong and very easily sculpted. You could suspend a 100g mass from a single human hair and it wouldn't break. But hair can easily be shaped by an enthusiastic hairdresser armed with combs, hairdryers and a few mysterious potions. The secret of its strength comes from the long, coiled strands of a protein called keratin that makes up the majority of each hair. The secret of the shape-shifting is in how those coils are attached together.

Before the rain started, each of the hairs tucked under my cycling helmet had a fixed shape. The coiled proteins are connected to the coils next to them with two types of bond. The strongest (called disulphide bonds) are pretty stable. But there are plenty of others (called hydrogen bonds) and these are fickle. As the first drops of rain found their way through my helmet, the water trickled into the gaps between the hairs, and then into the centre of the hairs themselves. This is where the trouble starts. When water reaches the hydrogen bonds, it disrupts them. So wet hair is weak – it's only held together by

some of the bonds that it had when dry. One of the things that hairspray does is to provide a barrier so that water can't get inside the hairs themselves. The weakening of these bonds also makes the coils stretch out a tiny bit – damp hair is longer than dry hair. In fact, this was used in the 1800s as a measure of humidity.

So as I was cycling along, my hair was wet, weak, and crushed by the helmet. I've got straight hair, and that's because the hairs themselves are round. Naturally curly hair is oval, and this means that when it gets wet,

**“If you don't have the appropriate tools, you spend the day looking like a drowned rat long after the water has evaporated”**



Next time you're having a bad hair day, blame it on the weakness of hydrogen bonds

it tends to coil up a bit more. When I arrived at work, the wet hairs finally began to dry out, and individual water molecules floated off into the air in my warm office. The problem with that is that as soon as they go, the hydrogen bonds reform, and they bond the protein coils together again as they are, in the flat, squashed, frizzy shape that the helmet pushed the hair into. This is why hair doesn't hold its shape on humid days – as soon as water gets into the hairs, the hydrogen bonds will continually break and reform, allowing the shape to change gradually.

Hair-styling is basically chemistry, and it wouldn't be possible without these two types of bonds. It allows such amazing variety – just the act of washing and drying your hair gives you the opportunity to give it a whole new shape. Unfortunately, if you don't have the appropriate tools to re-shape your hair as you'd like, you spend the day looking like a

drowned rat long after the water has evaporated. I think I'm going to invest in a new cycling helmet, and possibly pay a bit more attention to the rainfall radar before setting out! ■

**DR HELEN CZERSKI** is a physicist and BBC presenter whose most recent series was *Colour: The Spectrum Of Science*





## PATENTLY OBVIOUS with James Lloyd

Inventions about to change your world

### Grow your own grubs

EARLIER THIS YEAR, the UK's first insect restaurant opened its doors, and soon you'll be able to grow your own mealworms in the first desktop hive for edible bugs. Created by LIVIN Farms, the hive is a miniature insect ranch. Mealworm beetles in the top section lay eggs which grow into edible mealworm larvae that travel down the hive as they mature. Once they're 3cm long, the insects are ready to be harvested, and the hive can produce up to 500g of nutritious mealworms every week. Worm wonton might not be everyone's idea of a treat, but if you've caught the insect-eating bug, this will scratch that itch.

Patent pending

### Drop-in departures

FORGET FORKING OUT extra money to board the plane before everyone else. Airbus wants to speed up boarding times by fitting planes with removable cabin modules. Passengers would take their seats and get comfy inside a cabin module that's located within the airport terminal's departure lounge. Once all the passengers are in place and the flight is ready for boarding, the cabin module would be hoisted out and slotted into the plane like a Lego brick. This would cut down on airport space and waiting times, and – slightly less thrillingly – give you more time to get to know your in-flight neighbour.

Patent pending

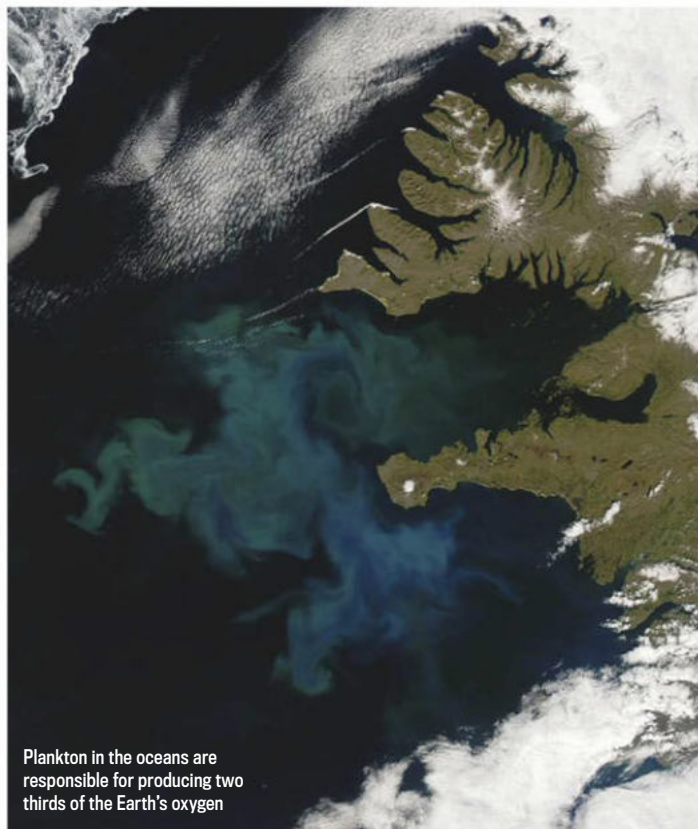
### Don't sweat it

IT'S NOT JUST probiotic yoghurt that's putting bacteria to good use. A project at MIT's Tangible Media Group is using moisture-sensitive bacteria to create clothing with active vents that open to cool you down when you get hot. The secret to the 'Second Skin' is a strain of the *Bacillus subtilis* bacterium that expands in response to humidity. A biofilm made from these bacteria is integrated into the fabric so that when the wearer starts to sweat, vents on the garment open up, helping the sweat to evaporate and cool your body.

Rather than just making your top stink, bacteria could help it keep you cool

## EARTH

# Climate change could suffocate Earth and its inhabitants by 2100



Plankton in the oceans are responsible for producing two thirds of the Earth's oxygen

WHEN IT COMES to climate change it's no time to breathe easy. Falling oxygen levels caused by rising global temperatures could result in the suffocation of life on Earth.

A study by mathematicians at the University of Leicester has found that an increase in the temperature of the world's oceans of just six degrees could halt the production of oxygen by phytoplankton by disrupting the process of photosynthesis. Alarmingly, some researchers have predicted that this could occur as soon as 2100.

"About two-thirds of the planet's total atmospheric oxygen is produced by ocean phytoplankton and therefore cessation would result in the depletion of atmospheric oxygen on a global scale. This would likely result in the

mass mortality of animals and humans," said lead researcher Sergei Petrovskii.

The prediction is based on a model that looks at the production and consumption of oxygen rather than carbon dioxide, which is more commonly used as an indicator of global climate.

"A lot has been said about the expected disastrous consequences of global warming since it became a concern almost two decades ago. Perhaps the most notorious is the flooding that may result from the melting of Antarctic ice if the warming exceeds a few degrees compared to the pre-industrial level. However, it now appears that flooding is probably not the biggest danger that global warming can pose to humanity," said Petrovskii.





# STEPHEN BAXTER SHORT ON SPACE

Will astronauts ever get to enjoy luxurious surroundings?

**J**ANUARY 2016 MARKS 30 years since the loss of the Space Shuttle Challenger. The orbiter had represented a brave attempt by NASA to design, in the wake of the Moon landings, an entirely new technological generation of spacecraft.

A winged spacecraft was an element of how the American future in space was supposed to have been. In the early 1950s Wernher von Braun – who had once worked on the V-2 programme for Nazi Germany – dreamed of huge winged rockets to carry astronauts to orbit, and a giant wheeled space station, a transit point at which missions to the Moon, Mars and beyond would be assembled.

The space programme of the 1960s didn't work out that way because of the pressure to get American astronauts to the Moon by the end of the decade. The Apollo spacecraft was a crude capsule, and the Saturn booster, though mighty, was in reality a descendant of von Braun's own V-2 ballistic missile. Even as the first astronauts reached the Moon, NASA was proposing von Braun's plans for the 1970s that would have included a winged spaceplane, a space station, and missions to the Moon and Mars. But in the end the Nixon White House accepted only the Space Shuttle proposal – leaving it to act as little more than a space ferry with nowhere to go.

By then, however, von Braun's vision had been immortalised in one of cinema's most glorious sci-fi visions – *2001: A Space Odyssey* (1968). The saga of alien contact shows a spaceplane, the 'Pan Am space clipper', and a wheeled space station, just as in the 1950s prospectus. Everything is clean, expensive and spacious. The clipper has a stewardess on board, and there's a Hilton hotel on the space station. Even the Discovery, the atomic rocket that takes astronaut Dave Bowman to Jupiter, is huge and elegant.

However, astronauts were finding that the reality of spaceflight was different. Spacecraft were fragile, crowded and grubby; the International Space Station is more like an explorers' shack than a hotel.

This new reality is reflected in the movies too: in *2001: A Space Odyssey's* sequel, *2010: Odyssey Two* (1984). By 1984 Apollo was already a 10-year-old memory, and the Space Shuttle had just begun flying. A new spacecraft called Leonov goes to Jupiter to retrieve the lost

**“Astronauts were finding that the reality of spaceflight was different. Spacecraft were fragile, crowded and grubby”**



Astronauts will need to wait a little longer for sleek, shiny and luxurious spacecraft

Discovery, and to seek the monolith-builders. The contrast between the spacecraft is striking. Leonov is an expression of the reality of spaceflight as experienced: cramped, uncomfortable, squat, ugly. When the two spacecraft are docked, it's a collision of 1980s reality with 1960s dreams.

Today the astronauts are back to riding the Russian Soyuz, a reliable but 1960s-vintage design, and NASA's new Orion spacecraft is a return to a similar capsule-based philosophy. But there are plans for new spaceplanes, such as the visionary British design Skylon. Meanwhile, space is not empty. If with the advanced drives of the future we can build craft that can get you to Mars in a matter of days or weeks, then even the very sparse interplanetary dust will be a significant hazard, and streamlining and shielding will be necessary. Perhaps even in deep space the future will see more elegance than the Leonov craft of 2010 would suggest.

In the end, we may remember Challenger and the other shuttle orbiters not as technical failures, but as brave attempts to realise expansive future visions. ■

**STEPHEN BAXTER** is a science fiction writer who has written over 40 books. His latest is *Xeelee: Endurance*

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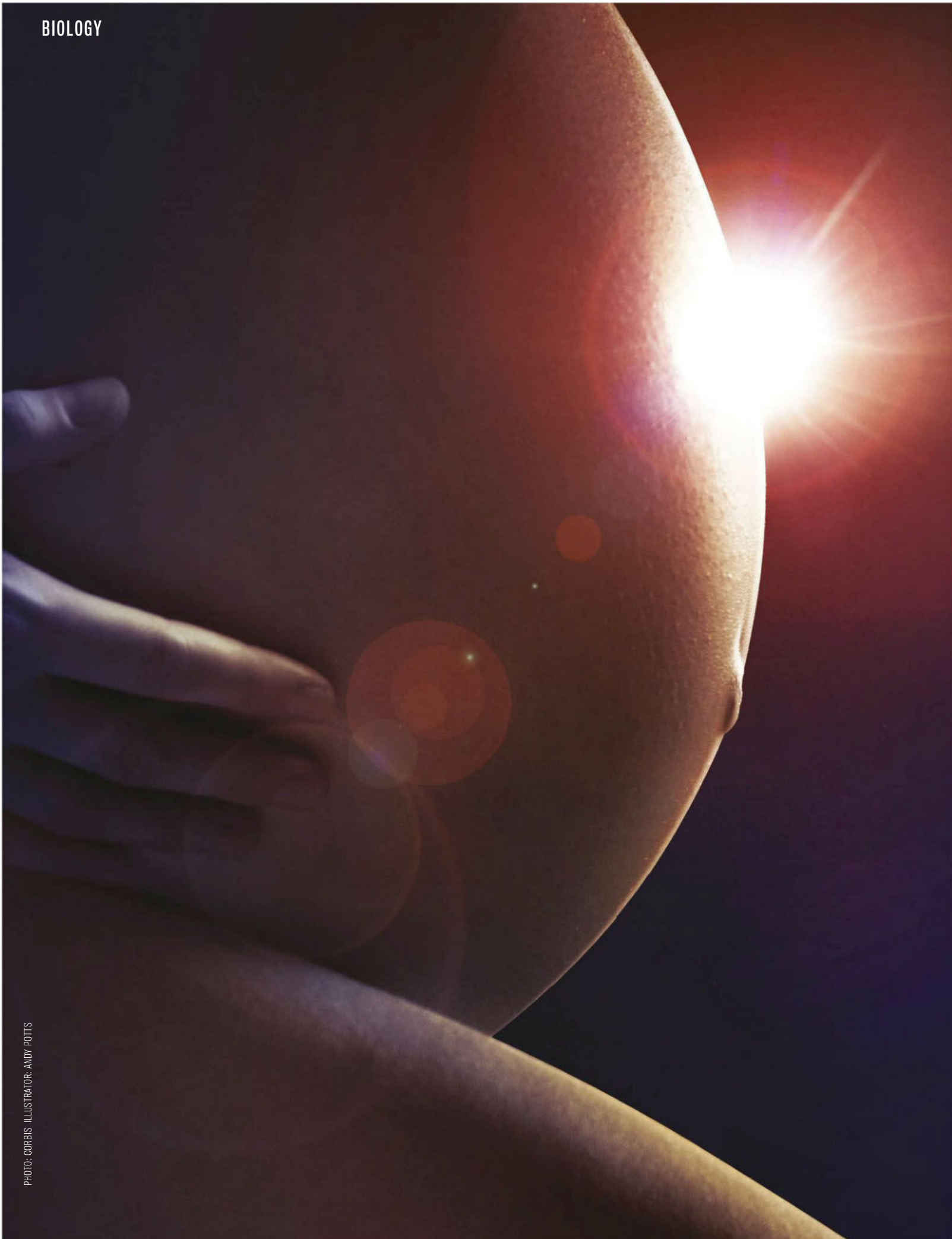
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# DAWN OF THE GM BABIES

This year, the UK could witness the birth of a child with DNA from three parents, as **Zoe Cormier** reports

**B**ACK IN FEBRUARY 2015, Parliament voted to amend the 2008 Human Fertilisation and Embryology Act to allow 'three-parent IVF' for families that carry mitochondrial diseases. These diseases are coded in the genes and are passed from mum to child via the mitochondria, the 'batteries' of the cell.

Mitochondria are tiny disc-shaped organelles (minuscule organs) carried within cells. The primary function of mitochondria is to produce ATP, the biological currency of energy. The number of mitochondria varies widely between cell types: red blood cells don't contain any, but liver cells can hold up to 2,000 each.

Human egg cells contain mitochondria the way most cells do, but sperm cells only have them in their tails. During fertilisation, the head of the sperm, which contains its genes, is inserted into the egg. The tail of the sperm – and therefore its mitochondria – is left behind. This is why all of us only inherit our mitochondrial DNA from our mothers.

Malfunctioning mitochondria can produce a wide variety of illnesses for which we have no cure. They regularly strike the organs that have the greatest energetic demands, including the kidneys, heart, liver, brain, muscles and central nervous system. Mitochondrial conditions are often fatal in infancy, but can frequently strike in adolescence or adulthood. It is estimated that one in 200 children in the UK carries some form of

genetic mutation that could lead to mitochondrial disease at some point in life. Every year, one in 6,500 babies is born with a mitochondrial condition so severe that they will not reach adulthood – or even their first birthday.

"Mitochondrial diseases are horrible and cruel – especially because as a parent there is nothing you can do," says Liz Curtis, whose daughter Lily died at eight months old from Leigh Syndrome. While Lily died when she young, others live for five or 10 years, slowly deteriorating. "To watch a child lose the ability to walk, talk, eat and eventually smile is crushing," says Curtis. She set up the Lily Foundation in her daughter's honour to support the families of children coping with mitochondrial conditions and to fund research into potential cures – because none were available to prevent Lily's death.

## SILENT KILLER

Currently in the UK, more than 150 children a year are born who will suffer severe mitochondrial disease – often unbeknownst to them or their families. And new research hints that mitochondrial anomalies may play a role in the diseases of old age, such as prostate cancer and Alzheimer's. Curtis, like most parents, had no idea she carried any gene that was faulty. "I'd never even heard of mitochondrial disease, nobody in my family had. It came completely out of the blue," she says.

## DNA deciphered

ALMOST ALL HUMAN DNA – 99.9 per cent of it – is contained in the nucleus at the centre of a cell. In the nucleus, information is stored and instructions are dispatched.

The three billion 'letters' of the human genome – which come in four chemical building blocks, called cytosine, adenine, thymine and guanine, are linked in long strands of DNA, called chromosomes. Each of us has 46 chromosomes, bound in 23 X-shaped pairs. The human genome consists of around 20,000 genes. Each gene is a stretch of DNA coding for a particular protein.

Other than the nucleus, the mitochondria are the only other organelles of the cell that contain DNA in their own genome. The mitochondrial genome – first discovered in the 1960s – is tiny, with just 37 genes. Though the mitochondrial genome accounts for just 0.1 per cent of the human genome, it holds the distinction of being the first portion of it to be fully mapped: geneticists managed to describe its contents in the 1980s, partly due to the fact that it is so small.



Right: Alana Saarinen was conceived by IVF, via a procedure that was banned by the FDA in 2001. Cytoplasm was donated from a younger donor's eggs into her mother's

➔ The main reason people like Curtis can carry a mitochondrial mutation, but not exhibit symptoms themselves, is due to a quirk of mitochondria called 'heteroplasmy'.

While the DNA in the nucleus of every single non-sex cell in the human body is identical, the selection of mitochondrial genes varies.

When one cell divides, its chromosomes are duplicated; each daughter cell receives identical chromosomes. But the tiny mitochondria – remember, there can be up to 2,000 of them per cell – are split randomly between the two daughter cells. Which cell gets which mitochondria carrying which genes is a matter of chance. This is why one sibling in a family may inherit a mitochondrial disease and one will not, and why a mother can unknowingly carry a dangerous gene.

Mutations that can lead to disease are therefore scattered randomly and unevenly between different cells. Disease-causing mitochondrial mutations vary not just between individuals, but between tissue types in one person: we are all mitochondrial mosaics. A certain 'threshold' amount of a malfunctioning mitochondrial gene in any given cell needs to be reached for an illness to manifest.

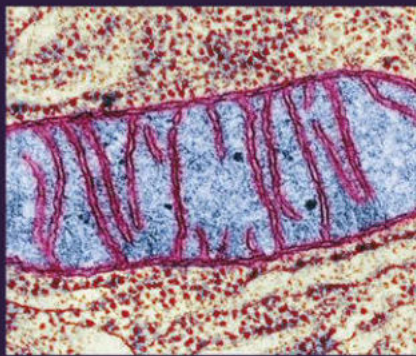
## ALTERED EMBRYOS

The technique that was legalised in the UK at the beginning of 2015 will allow a mother to give birth to a baby that is genetically hers, but there will not be the risk of it inheriting mitochondria with dangerous mutations. The process is known as 'mitochondrial donation' or 'mitochondrial transfer'. A mother-to-be carrying faulty mitochondria can opt to have her nuclear DNA removed from her eggs and implanted into a donor egg carrying healthy mitochondria. The egg is then fertilised with sperm from the father before being implanted into the mother's uterus for pregnancy to continue as usual.

A recent study from the Wellcome Trust Centre for Mitochondrial Research at Newcastle University estimated that 2,473 women in the UK are at risk of passing a mitochondrial



Mitochondria are the 'batteries' of cells, but also contain their own DNA



**“[Mitochondrial diseases] can be extremely debilitating and it's heartbreaking for the parents”**

Shamima Rahman, Professor of Paediatric Metabolic Medicine at UCL Institute of Child Health

disease to their children and thus could benefit from the treatment.

“I'm over the moon that the law was changed. It's hugely rewarding to know that families can have their own child that will be free from disease,” says Curtis.

## THREE PARENTS?

Children who would be conceived in this way have been dubbed 'three-parent babies' by the press, as they technically carry DNA from three people (albeit just 37 genes from the donor egg, compared to 20,000 from the mother).

“It's unfortunate that the 'three-parent baby' term was coined,” says Shamima Rahman, a Professor of Paediatric Metabolic Medicine at the UCL Institute of Child Health, who began working with mitochondrial diseases 20 years ago. “I was very concerned that we were seeing a group of disorders that nobody really knew anything about, much less how to treat. They can be extremely debilitating and it's heartbreaking for the parents.”

Aside from sensationalism, the 'three-parent' nickname is misleading, in several respects:

One, the female mitochondrial donor is not likely to have any role whatsoever in bringing up the child. Two, the amount of DNA carried in the mitochondria – just 37 genes in total, compared to 20,000 in the



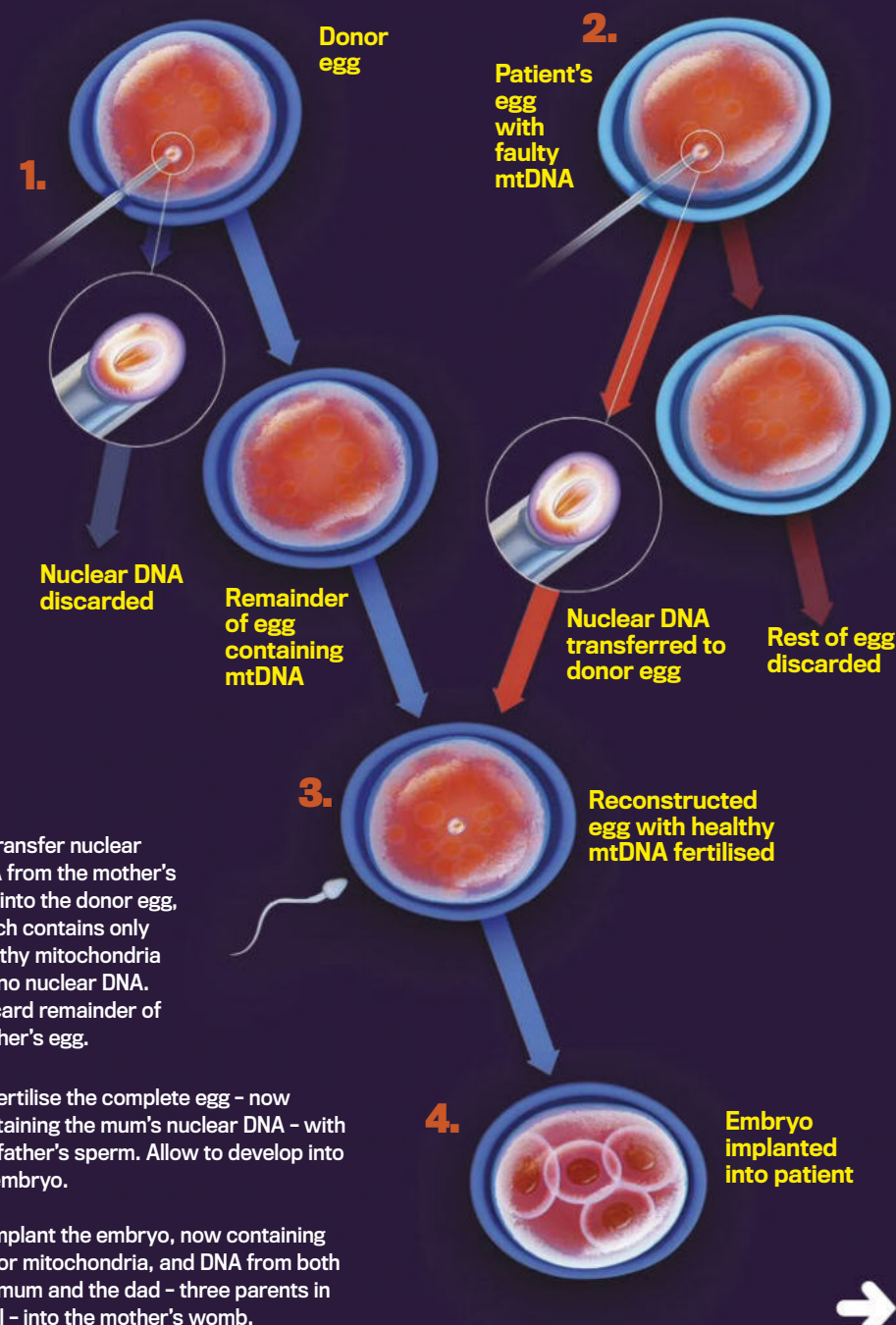
## HOW IT WORKS:

There are several techniques for creating a baby from three parents. Here are two of them...

### SPINDLE TRANSFER

1. Start with two eggs – one from a mum-to-be with diseased mitochondria, one from a donor with healthy mitochondria. Remove nuclear DNA from both eggs.

mtDNA = mitochondrial DNA



nucleus – is tiny, a mere 0.1 per cent of the entire genome.

And three, children have already been born who carry DNA from three parents.

Women who act as surrogate mothers have been found to pass minute amounts of mitochondrial DNA to the babies they carry for nine months. Meanwhile, in the late 1990s, children conceived through 'ooplasmic transfer' – an IVF technique used to bolster the viability of eggs by injecting cytoplasm from young donor eggs into the older eggs of women undergoing fertility treatment – were later found to carry small amounts of DNA from the donor. Some of the resulting children are alive and well. The US Food and Drug Administration (FDA), however, put the brakes on this treatment back in 2001, and has yet to approve the new mitochondrial donation technique.

Yet mitochondrial donation is distinct from surrogacy and cytoplasmic transfer for one simple reason: it is overtly intended to create children with DNA from three parents. Thus there is something inherently more unsettling about deliberately seeking to alter the inheritable DNA of a child. Unlike a course of drug treatment, genetic changes are permanent. *The New York Times* called the creation of "genetically modified babies" (an undeniably emotive descriptor) "a dangerous step" and an

"extreme procedure" in a 2014 opinion piece by Marcy Darnovsky, Executive Director of the Center for Genetics and Society. Naturally, this led to fears that mitochondrial donation could lead to 'designer babies' (despite the fact that mitochondrial genes do not code for visible traits such as eye colour). A Republican representative for Nebraska, Jeff Fortenberry, went so far as to call it "a macabre form of eugenic cloning".

Knee-jerk reactions aside, there are reasons to be cautious. Research is increasingly revealing that mitochondria are far more important than mere

'batteries', and have duties that include influencing the speed of nerve signalling, detoxifying ammonia in the liver, and playing a key role in programmed cell death. Moreover, genetic information is continually shuttled between the nucleus and the mitochondria. This implies that shifting mitochondria from one woman to another could have unexpected consequences down the line.

The most distressing fact about mitochondrial replacement, however, may be that it will only work for a minority of families carrying mitochondrial diseases.





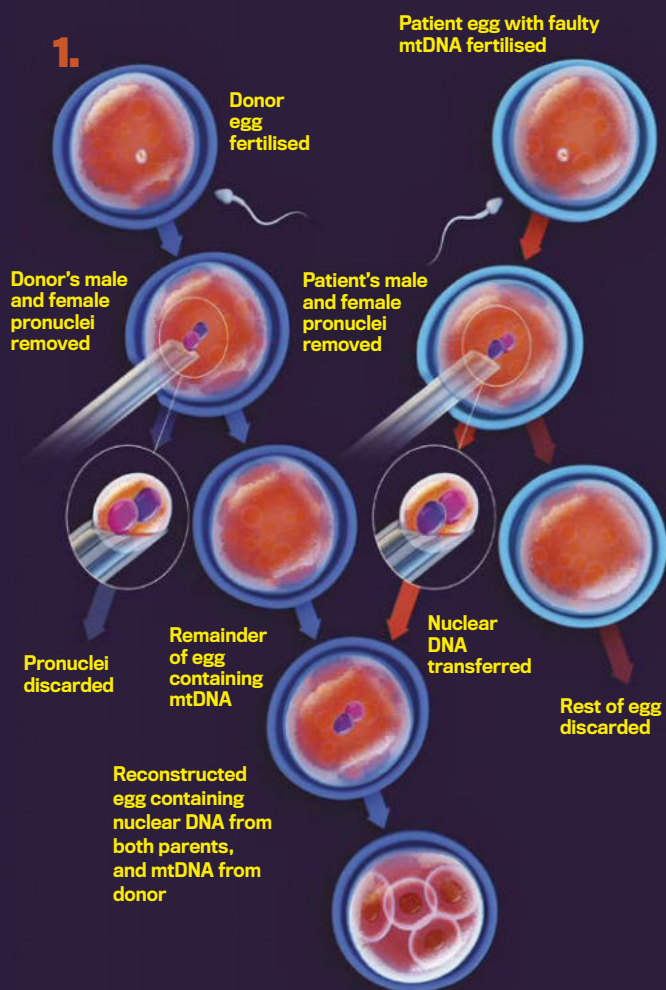
## PRONUCLEAR TRANSFER

**1.** Start with two egg cells – one from a mum-to-be with diseased mitochondria, one from a donor with healthy mitochondria. Fertilise both with the dad's sperm.

**2.** Remove the pronuclei – the nuclei of the egg and the sperm, which have not yet mixed together – from both eggs. Discard the rest of the mother's egg. Discard donor's pronuclei.

**3.** Inject the pronuclei of the mother and the father into the donor's egg, which contains healthy mitochondria.

**4.** Implant embryo, which contains mitochondria from the donor, and DNA from both the mother and the father – three parents in total – into the mother's womb.



mtDNA = mitochondrial DNA



➔ We now know there are 1,000 – possibly 1,500 – genes in the DNA of a nucleus that code for proteins necessary for the creation of mitochondria. Yet many of these genes can also lead to faults. It is likely that only a quarter of all cases of mitochondrial disease can be attributable to genes within the mitochondria themselves. “Even from very early on, more than 20 years ago, it was clear that most of the children with mitochondrial diseases don’t carry mitochondrial DNA mutations,” explains Rahman.

In other words, three-quarters of families carrying mitochondrial diseases somewhere in their lineage will not be able to use mitochondrial donation to protect their children.

Nonetheless, the Human Fertilisation Embryology Authority carried out three

Louise Brown holding the test tube in which she was conceived







Left, from top to bottom: IVF pioneer Robert Edwards holding Louise Brown with gynaecologist Patrick Steptoe; IVF is common today, but Brown's birth was headline news at the time; Brown holds Matthew Shepherd - the 1,000th baby born via IVF



Could mitochondrial donation become as mainstream as IVF?

## "This is world-leading science within a highly respected regulatory regime"

MP Jane Ellison, Parliamentary Under-Secretary of State for Health

scientific reviews of the treatment, and concluded that it was safe.

"It is a bold step for Parliament to take, but it is a considered and informed step," MP Jane Ellison, Parliamentary Under-Secretary of State for Health, told the

House of Commons in February 2015. "This is world-leading science within a highly respected regulatory regime, and for the families affected it is a light at the end of a very dark tunnel."

### GROUNDBREAKING SCIENCE

On 25 July 1978, Louise Brown – the first ever test tube baby – was born in Oldham General Hospital to her parents, John and Lesley. At the time, concerns were raised about 'Frankenbabies' and 'playing God', while certain members of the public subjected the Browns to hate mail and ridicule. Today, however, more than five million children have been born via IVF.

Ultimately, doctors are confident that this new technique will follow in the path of IVF to become a routine treatment that could transform lives. ■

## PRE-BIRTH THERAPIES

### Blood transfusions

Since 1989, foetal blood transfusions have been successfully performed. They involve injecting donor blood into a developing foetus (usually through the umbilical cord). They are used for conditions such as bare lymphocyte syndrome, an immune disorder, and severe combined immunodeficiency (SCID) or 'bubble boy syndrome'.

### Stem cell transplant

Blood transfusions are usually given to patients only once symptoms of diseases appear. But to treat inherited conditions such as SCID and sickle cell anaemia much earlier, researchers are trialling treatments that involve injecting donor stem cells into a foetus. No human trials have taken place yet but animal studies are promising.

### Prenatal gene therapy

Gene therapies, which use modified viruses to deliver genes into a patient's nuclear DNA, have been used for over 20 years to treat adults and children with certain diseases. But for many conditions, such as cystic fibrosis, organ damage has already taken place by childhood – sometimes even before birth. By treating foetuses in the womb, researchers hope to stop damage before it starts. There have been successful trials in mice, monkeys and sheep.

### Foetal 'priming'

Researchers are exploring the potential to 'prime' the immune systems of developing foetuses by transplanting proteins (rather than genes or entire cells). Adults with haemophilia can be treated with injections of blood clotting proteins, but about one-fifth of people reject the donor proteins. By 'priming' the immune systems of foetal mice with umbilical cord injections of the protein, the baby mice were more likely to accept transplants after birth.

ZOE CORMIER is a freelance science journalist and founder of Guerilla Science

# FORMULA DRONE

In sleepy corners of the UK countryside, a new sport is emerging. **Rob Banino** dons his flying goggles to go drone racing

ALL PHOTOGRAPHY BY SAM HOBSON

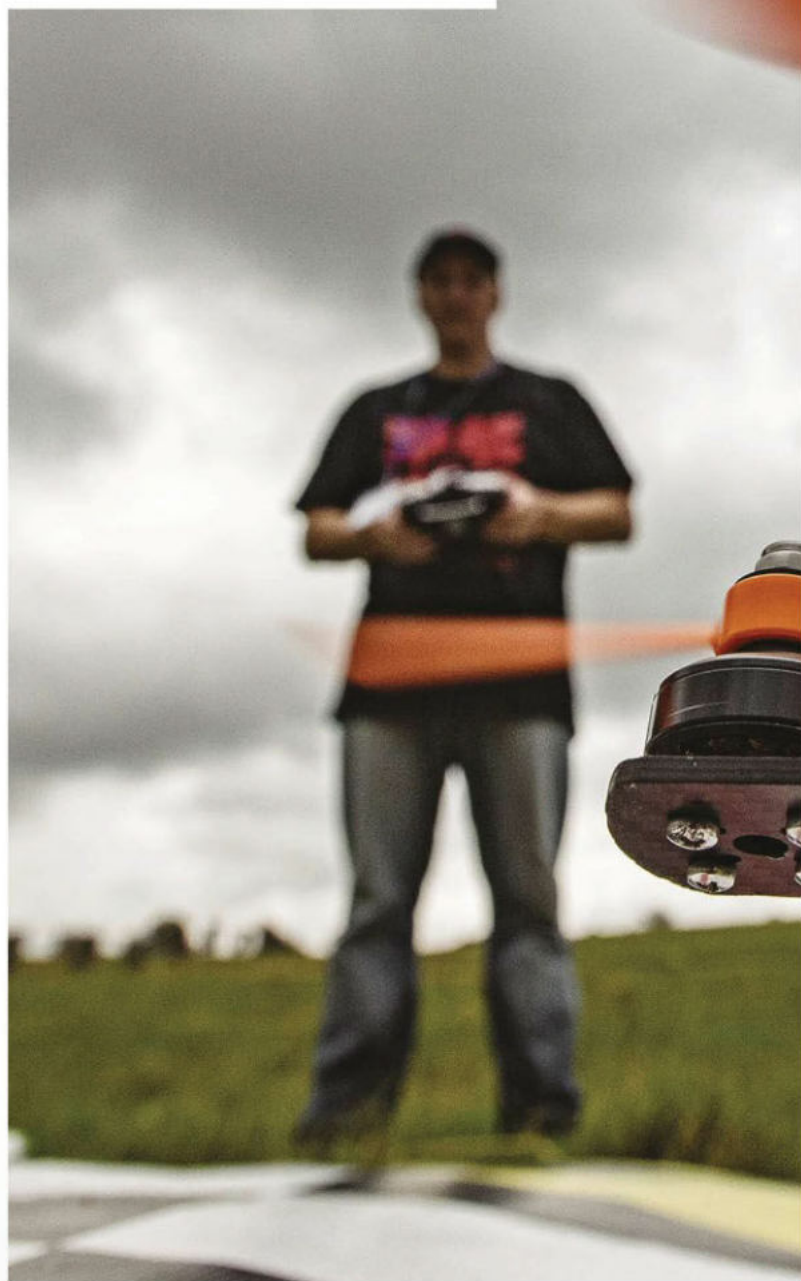
WEEKENDS AT THE Cowdray Estate in West Sussex are busy. The grounds around the Tudor mansion are usually used for clay pigeon shooting, fly fishing, golf and polo matches. But the small crowd of men gathered in a corner of one of the estate's fields on this particular Saturday morning are here for a different reason.

As shotgun fire echoes in the sky nearby, some of them fiddle with radio and video equipment while, a short distance away, others lay out a series of cones and gates. With all the power cables, generators and tools lying about, you'd be forgiven for thinking this was a crew of roadies setting up the backstage area for a concert. But it's actually a pit area and the cones and gates are taking the shape of a race circuit – because these men are here to race drones.

## A DIFFERENT POINT OF VIEW

A racing drone (or, more accurately, quadcopter) is like any other drone except for two key differences: how it's built and how it's flown. Racing drones are built to be lighter, faster and more manoeuvrable than your typical shop-bought drone, so they're stripped down to the bare essentials: a carbon-fibre chassis, battery, motors, propellers, radio equipment and an onboard video camera. The video camera is essential, because flying drones at the speeds they're raced at – anything up to 100km/h – can't be done with traditional line-of-sight perspective. It's only possible with the first-person view the onboard camera provides.

Mounted on the front of the drone, the camera 'sees' whatever's going on









➔ in front, whether it's clear sky, a rival racer or the next turn or obstacle on the circuit. That view is transmitted to two small screens in goggles that the pilots wear, so that rather than trying to fly the drone by watching it from afar, the pilot sees the race from the drone's perspective.

"The first-person view (FPV) element is crucial," explains race organiser Niall Sheffield. "Without it, it's really hard to keep track of your orientation. If the drone's flying away from you, right is right and left is left, but as soon as you turn and start to fly in another direction, everything changes. The other problem is perspective. If you're trying to fly it through a gate, you need to see how far away the gate is to gauge your approach or else you'll fly into it or miss it completely."

Denis Graton, a French-Canadian, is the man generally considered to be the father of FPV flying. "[Graton was] using disassembled home-security video components and homemade goggles to fly his model plane around golf courses," says Simon Dale, founder and chairman of the First Person View UK Association.

"My father and I saw the videos of his flights that he posted online back in 2007 and thought it was amazing so we tried to emulate Denis here in the UK. It took a while but we eventually sourced some decent kit and got it working tolerably well. So then we decided to build a website and sell the equipment for others to enjoy."

## LOWER TECH, HIGHER SPEEDS

Video technology may have made drone racing possible, but we're not exactly at the bleeding edge of AV technology here: video is transmitted to the pilots' goggles as an old-fashioned analogue signal. There's a very good reason for using analogue transmissions, though: they can be processed much more quickly than digital



Rob tries a pair of FPV goggles on for size

signals. An analogue signal carries less information than a digital one, so it can be coded, transmitted, received, decoded and displayed faster, providing the pilot with a real-time view, whereas the extra time required to process and display a digital signal creates a delay between what the drone and its pilot are seeing. It's not a lot, but even the slightest delay is enough to make flying around tight turns and obstacles much harder.

And those turns and obstacles are hard enough to handle as it is – as the pilots racing at Cowdray Estate demonstrate. The initial qualification heats start with four pilots in each race, but it's rarely more than two of them that manage to reach the finish. Nevertheless – or perhaps for that very reason – the races are exciting to watch.

There are two ways you can do that: you can witness the whole race unfold in front of your eyes or don your own goggles and tune in to a particular pilot's view. Either way, the sight of four small aircraft performing almost-synchronised aerial acrobatics at high speed is as thrilling as the mid-air collisions.

## HOW TO FLY AN FPV DRONE

From purchase to take-off

### GEAR UP

"If you want to get a quadcopter in the air, it'll cost about £90," says drone racer and race organiser Niall Sheffield. "But that's just for the quadcopter itself. If you want to fly by first-person view (FPV), then you'll need a few other pieces of kit – notably the goggles. But you can get a quad flying by FPV with a couple of batteries and a charger for about £230 in total, so it's still pretty reasonable."

### SAFETY

Price isn't the only concern – safety is another important issue. Drones are categorised as small unmanned aircraft and, in the UK, have to be flown in accordance with the relevant laws issued by the Civil Aviation Authority. FPV drones must be flown with a spotter looking out for the pilot.

### TAKE-OFF

As for the actual flying, it's easy to pick up with a bit of patience and practice. The drones may not have wings but the throttle, pitch, yaw and roll control principles are the same as with any other aircraft. The key difference is that rather than altering the angle of the aircraft's wings and rudders to change direction, the drone's control unit alters the speed of each propeller to adjust its flight path. It's similar to how a car's traction control system slows a given wheel to stop it skidding, but in three dimensions rather than two.

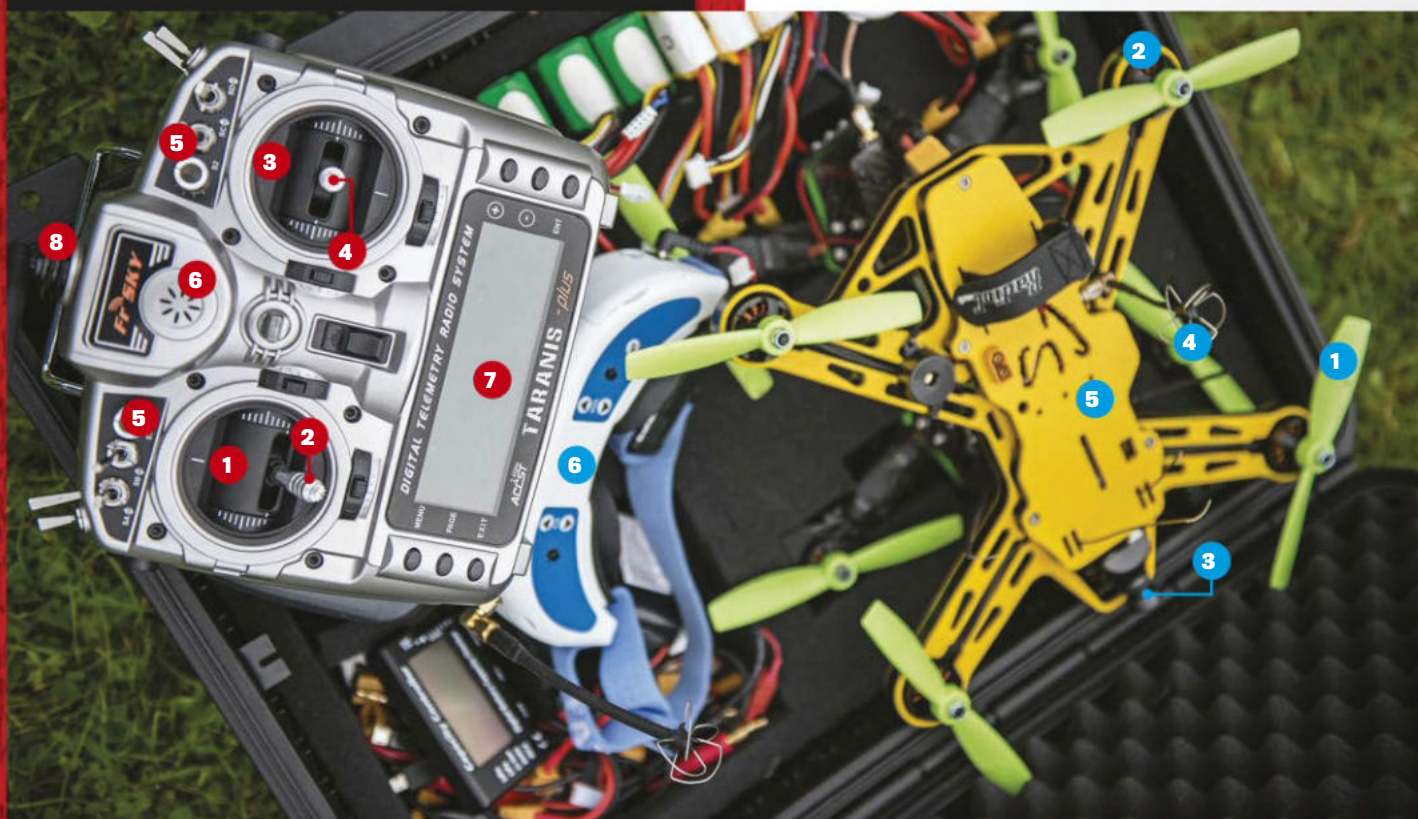
The other thing to bear in mind is that it's a good idea to sit down while flying by FPV, as the perception of motion through the goggles can be enough to make people fall over.





# ON THE CONTROLLER

# ON THE DRONE



## 1. THROTTLE

Controls the height of the drone.

## 2. YAW

Rotates the drone around a central vertical axis allowing it to turn left or right.

## 3. PITCH

Tilts the angle of the drone, allowing it to point up or down.

## 4. ROLL

Rotates the drone around a horizontal axis along its length, allowing it to bank.

## 5. SWITCHES

These can be configured to each pilot's requirements using open-source software. They can be used to control various flight settings, such as the amount of automatic stabilisation, and also to turn the video camera on and off.

## 6. SPEAKER

Provides audible alerts.

## 7. DISPLAY

Can be configured to show the drone's performance telemetry and provide visual alerts regarding the remaining battery life.

## 8. ANTENNA

Used to send commands to the drone, and receives back telemetry (performance data).

## 1. PROPELLER

Drones are often classified by the number of propellers. So a drone with four props is a quadcopter, one with six is a hexacopter, and so on. Quadcopters are the most popular for racing.

## 2. MOTOR

A small electric motor drives each propeller. The speed it spins at is determined by the drone's flight control software, which increases or decreases the speed of each prop so the drone responds to the pilot's inputs accordingly.

## 3. CAMERA

Mounted on the front of the drone, a video camera films a view of everything that lies ahead of the drone as it flies. The images are streamed back to binocular screens in goggles worn by the pilot.

## 4. ANTENNA

Transmits the analogue video signal from the drone's camera back to the pilot's goggles to give a first-person-perspective view of the drone's flight.

## 5. CHASSIS

Typically made of carbon fibre, this holds the battery, flight control unit, radio equipment, camera and the arms upon which the motors and propellers are mounted.

## 6. GOGGLES

Contain a pair of small screens and magnifying lenses that provide the pilot with binocular images of the view being filmed by the camera that's mounted on the drone.





➔ It's exciting for the pilots, too, who often raise their goggles after finishing a race – whether they crossed the line or crashed and burned – to reveal a look of sheer exhilaration.

"It's a bit of an out-of-body experience," says Niall when describing what FPV flying is like for the pilots. "If you're playing a videogame there's always a disconnect between you and your avatar, because you can see everything between you and the screen. But when you put on the goggles that disconnect disappears and you can almost forget that you're on the ground. It's like you're actually flying."



## THE BALANCING ACT

Switching between piloting and spotting allows racers to compare notes on the circuit and the fine-tuning of their drones. Getting the best out of a drone means striking a delicate balance between speed and handling. While bigger propellers and more powerful motors will generate more thrust, they will also drain your battery faster. And although you can add more batteries to compensate, doing so means adding more weight.

"Your battery has more of an impact on performance than you might think," says Niall. "It's not like the battery in a phone or a laptop, where power drains at a more-or-less constant rate. With drones, it's about the maximum amount of power you can draw from that battery in any one go – what's called the burst-discharge rate. So there's a trade-off involved: you can have more batteries but if you add more weight, it'll take more power to keep the drone in the air, which also means you'll get less flight time because you're taking more



Clockwise from top left: race winner Francis Harris; Rob with Fes Askari from First Person View UK; on the starting grid; tweaking a drone's settings before the race begins

power out of the batteries. It's a big balancing act."

But it's a balancing act the pilots at Cowdray Estate learn quickly. Once the heats are out of the way the speeds begin to climb as the lap times drop. The semi-finals are raced at a blistering pace before the pilots that qualify for the final retire to adjust their drones for the last race.

With no more races to hold anything back for, the final is a full-throttle affair. The drones tear past the pit area before slicing through the circuit's turns and







Right: Even in a non-contact sport like drone racing, injuries can still occur  
Far right: Each drone pilot (front) must be accompanied by a 'spotter'



**“When you put on the goggles, you can almost forget you’re on the ground”**



gates. It only takes a few minutes of frantic action for Francis Harris to emerge as the day’s victor. The young man from Brighton brings his drone in to cheers and applause from the small crowd before being presented with his prize (a £50 voucher for more drone kit).

The sport is still in its early days but has already garnered an enthusiastic and skilful group of competitors. So what’s next for them and the sport? “We want to bring spectators into the sport more, with big screens showing onboard footage,

commentary, lap times and so on,” says Simon. “I think this will make it a lot more accessible and allow the sport to become a mainstream thing.

“Racing is such a good story to counteract the constant media coverage of sensationalised bad news [regarding drones],” he continues. “We love being involved with it for that reason. The way the races are run – in fields in the middle of nowhere, cordoned off from the crowd, never flying higher than about 20ft, with everyone briefed and following instruction

– makes it incredibly safe.” And, perhaps more importantly, a lot of fun. ■

**ROB BANINO** is a freelance technology and sports journalist, and a former *Focus* Production Editor

**DISCOVER MORE!**

**BBC iPlayer** In April, *Click! went* to the Drones World Cup in Dubai |  
– see the episode on BBC iPlayer|



## INTERNET BY BALLOON 2016, DATE TBC

Google's status within the online world looks set to soar in 2016, as its internet-delivering Project Loon takes off. Each helium-filled, polyethylene balloon is capable of beaming wireless internet across 80km of land by tapping into the telecommunication networks of phone providers and relaying it to the ground via radio antennae. The short-term aim is to connect up 300 balloons in a ring around the southern hemisphere.

# 2016

What does the new year have in store for us? **Hayley Birch** looks ahead...

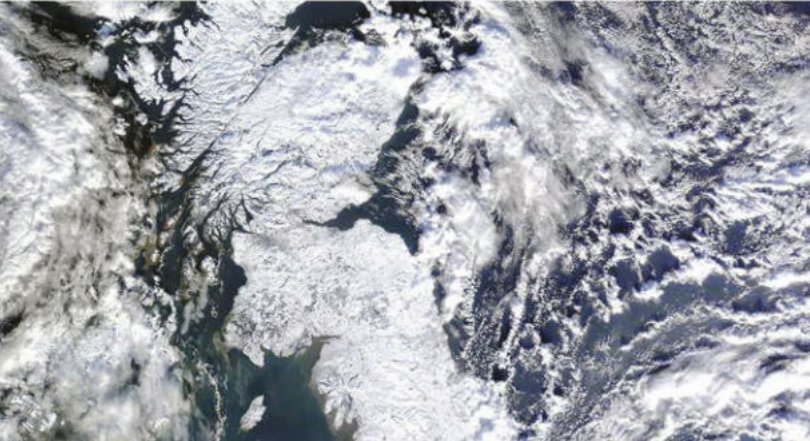
## A YEAR IN SCIENCE

## GO WILD FOR CATS 2016, DATE TBC

Big cat sightings in the UK are taken about as seriously as Bigfoot sightings in North America. But in 2016, scientists and conservationists hope to reintroduce the Eurasian lynx to selected sites across England and Scotland. Though common across the rest of Europe, the cat has been absent from the UK for over 1,300 years, after being hunted to extinction. It is roughly twice the size of a domestic cat.

**"Scientists and conservationists hope to reintroduce the Eurasian lynx to selected sites across England and Scotland"**





## THE WINTER TO END ALL WINTERS JANUARY/FEBRUARY

Despite mild beginnings, temperatures could drop dramatically during winter 2015/2016, as the British weather falls foul of a stronger-than-usual El Niño event. Originating as a temperature increase in the eastern tropical Pacific Ocean, El Niño influences weather patterns worldwide through changes in wind direction. UK meteorologists are already predicting gale-force winds and temperatures similar to those of 'The Big Freeze' in 2009-10, when the average December temperature was lower than for any other year on record.



## A NEW ERA FOR HYDROGEN CARS SPRING

Due to hit showrooms in spring 2016, the Honda Clarity will become the third car available in the UK that uses hydrogen fuel cells. Like competitors from Toyota and Hyundai, the Clarity burns hydrogen to produce electricity, but Honda reckons it will run about 45 per cent further on a full tank than Toyota's and 18 per cent further than Hyundai's. The issue is the lack of hydrogen fuelling stations – only a handful are open to the public.



## WOMB TRANSPLANT TRIALS SPRING

Following the births of four babies in Sweden to mothers who had successful womb transplants, the UK and US are planning new trials. UK surgeons will transplant wombs from braindead patients into 10 women born without wombs or who had them removed due to cancer. The women will have to take drugs to stop their bodies rejecting the organs but, all being well, should give birth to the first British babies born from womb transplants by 2018.

## "This summer will see a 2km plastic-catching structure deployed near Tsushima"



## THE GREAT OCEAN CLEAN-UP SUMMER

You expect students to be distracted by Netflix, but cleaning up the entire ocean? Boyan Slat quit his course at Delft University in the Netherlands after he became hooked on the idea of building floating platforms to collect marine waste. By 2014, he'd raised over \$2m to help trial the system. This summer will see a 2km-long plastic-catching structure deployed near the Japanese island of Tsushima.



## JUPITER UNCOVERED JULY

In 1973, Pioneer 10 became the first spacecraft to perform a flyby of Jupiter, snapping pictures of the planet from 130,000km away. This year, NASA's Juno spacecraft will get much closer to the gas giant as it performs a dizzying series of manoeuvres just 5,000km away. Charged with uncovering the secrets of Jupiter's origins, Juno will make 32 spinning circuits, using its instruments to probe the planet's gravitational and magnetic fields and investigate whether or not it has a rocky core.

## BIGGEST EVER TELESCOPE SEPTEMBER

The world's biggest and most sensitive radio telescope may be called FAST (the Five-hundred-metre Aperture Spherical Telescope) but it has taken over 20 years to come to fruition. The project was first proposed in 1994, and is being built in a remote location in the mountains of southern China. When complete, it will cover an area larger than Beijing's Forbidden City palace complex. The enormous structure will then begin searching for signs of life among the radio signals from outer space.





# ARE WE LOOKING FOR ALIEN LIFE IN THE WRONG PLACE?

There's been a lot of talk recently about looking for extraterrestrial life. We're bombarded with stories about life on Mars or habitable worlds circling other stars. But could this be blinding us to better places to look for life? **Stuart Clark** investigates

**T**HE ICY MOONS of the outer Solar System are attracting more and more attention from planetary scientists. Decades of studies have shown that there is a lot of liquid water locked away inside the outer moons. On Earth, pretty much anywhere you find water, you find life – so could be the same be true of the outer moons?

"In terms of potential habitats, I think most [astronomers] are fairly sure that there are places inside many of these moons where, if you put the right kind of organism there, they would survive. So we've got habitats, we just don't know whether they are inhabited by organisms," says David Rothery, a planetary scientist from the Open

University, UK, who surveyed the moons of the Solar System for his book *Moons: A Very Short Introduction*.

Looking for life beyond Earth is no mere exercise in intellectual curiosity, either. Should we ever find any such life, it should tell us more about how life began here on our own planet.

At present, no one knows exactly what conditions are needed to flick the switch from mere chemistry to biology. Did this process occur readily, or was it the result of a chain of unlikely events? That's something that finding life elsewhere would help us answer.

"If we can find places in the Solar System where life began independently from life on Earth, then... wow! That is pretty compelling evidence that if life can start, it will start," says Rothery.

Life needs a power source. Once, we thought that the only suitable source of such power in the Solar System was the Sun, which meant that life had to exist on a planet's surface. Hence the interest in Mars, which seems to be the most Earth-like of the other planets. However, a discovery on the floor of the Pacific Ocean in 1977 changed all that.

Researchers from the Scripps Institute of Oceanography in California were exploring around the volcanic ridge known as the East Pacific Rise. They







# Europa

**Parent planet: Jupiter**

**Orbital period: 3.551 days**

**Radius: 0.245 Earth radii**

**Mass: 0.008 Earth mass**

**Planetary Habitability Index: 0.49**

THIS WAS THE moon that opened up our eyes to the possibility of oceans in the outer Solar System. Suspicions first arose in the late 1970s, when NASA's Voyager 1 and 2 spacecraft passed the moon. The images showed a mostly smooth icy surface, almost devoid of craters. Since these impact scars accumulate as time goes by, for Europa to show hardly any meant that the surface was being renewed. But how?

Cracks on the surface provided us with an answer. In the 1990s, NASA's Galileo spacecraft explored the moon and revealed that dark materials around the cracks were salty, as if they had come from an ocean. Magnetic readings also hinted at a shifting body of water inside the moon. The final piece of the puzzle came in images of the surface, which clearly showed ice floes.

The heat to keep this ocean liquid was calculated to be coming from the gravity of Jupiter. A so-called tidal force squeezed the moon, producing friction to melt the underground ice and maybe even drive black smokers. But getting down to see them will be tough. The ice sheet that makes up the surface of Europa is estimated to be between one and 10 kilometres thick.

"It would be very difficult to go to Europa, drill through the ice and send a submersible to the black smoker on the ocean floor, but you could potentially land at one of the cracks and sample the slush that's squeezed up through it," says Rothery.

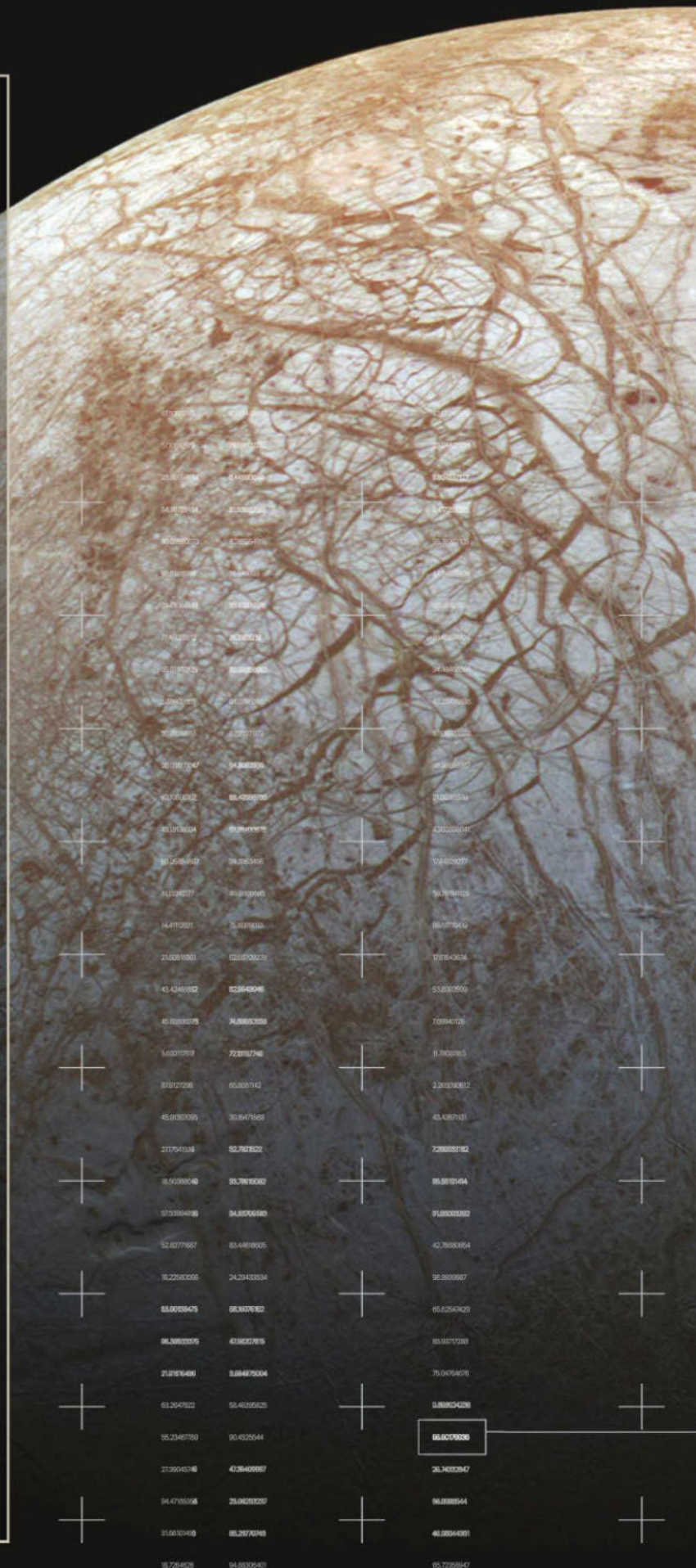


This would allow equipment to look for biologically important molecules. The kit would have to be designed to work in high radiation levels. Every day the surface of Europa is bathed in thousands of times more harmful radiation than Earth. An astronaut standing on Europa would receive a fatal dose within 24 hours. Luckily for any life on the ocean floor, the radiation will not penetrate beneath the ice sheets.


NASA is developing a mission to study the moon from orbit. Called the Europa Multiple-Flyby Mission, the space agency is currently designing the instruments that will allow it to assess the moon for habitability. Intended for launch in 2022, the spacecraft could carry a lander built by the European Space Agency (ESA).

ESA itself has a mission to Jupiter called Juice (Jupiter Icy Moons Explorer). Although not designed to concentrate on Europa, it will be making some flybys of the moon, during which it will use its ice-penetrating radar to measure the thickness of the ice crust.

PHOTO: GETTY







Europa is believed to have an ocean of liquid water below its icy crust. Below the water is rock; below the rock is the moon's solid core

Europa is covered with cracks and streaks, but there don't appear to be many impact craters

**"It would be difficult to go to Europa and drill through the ice, but you could land at one of the cracks and sample the slush"**

David Rothery, The Open University





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30.570093	35.4314322	66.42900458	30.9647689	41.42280435	79.7500019
63.3190196	40.8955295	95.48983201	52.7621622	11.69524045	1.592981599
76.3193219	5.78127824	26.78952953	66.7891962	56.319943	84.35448251
66.5839063	74.7768837	62.5810376	34.8372889	56.6875488	6.365530464
64.0799047	20.8110473	26.89723982	65.4481969	56.8193675	5.709039129
6.52927177	88.0192942	33.58356409	24.29430534	9.337016525	1.079191919
64.8822336	58.0304318	96.81997246	66.1627852	3.318251837	1.079191919
66.4898778	53.5448788	3.543954026	47.66207815	1.079191919	1.079191919
57.86400679					
24.9093498					
48.8703950					
75.16319012					
62.96797					

Enceladus is believed to have a low-density rocky core and an icy outer shell, with an ocean of liquid water sandwiched in-between



# Enceladus

**Parent planet: Saturn**

**Orbital period: 0.395 days**

**Radius: 0.0395 Earth radii**

**Mass: 0.000018 Earth mass**

**Planetary Habitability Index: 0.35**

ALTHOUGH EUROPA WAS in many ways the trailblazing moon for sub-surface oceans, much remains unknown because the water is mostly locked under the ice. At Enceladus, however, nature has gifted us a way of analysing

the ocean just by flying past the world. This is because there are geysers jetting water from the ocean into space.

NASA's Cassini spacecraft has been targeting those plumes and flying through them, so that its onboard instruments can analyse them. Various types of dust grains and chemical have been discovered in this way, including the telltale signature of salts.

"This is pretty good evidence that we are sampling the ocean itself," says Jonathan Lunine, a planetary scientist at Cornell University. Spurred on by the



**“Enceladus is almost certainly habitable – we just don’t know whether it’s inhabited”**

David Rothery, The Open University

discovery of Enceladus’ water plumes, the spacecraft operators designed a sequence of flybys that would take Cassini deeper and deeper into the plumes.

“We now have an inventory of organic molecules,” says Lunine. “It is not a complete list but it is enough to be able to say, yes we have carbon-bearing molecules inside Enceladus.” This could be a significant discovery, because on Earth, life-giving DNA is built using carbon-bearing molecules.

On 28 October 2015, Cassini plunged to its closest flyby yet, just 48km above the icy surface and hopefully steering through the densest part of the geysers. Planetary scientists are now eagerly

analysing the results. They are on the look out for molecules of hydrogen, because if this gas is present in the water jets, theory suggests that it must be coming from where hot water is reacting with rocks on the ocean floor.

Finding the molecule has implications for life. “Hydrogen can feed an organic pathway. A microbe could bond hydrogen onto carbon and get an energy kick out of it,” says Rothery. This is how microbes called methanogens survive on Earth.

Of course, finding the chemical ingredients for such life does not

guarantee that it is there. Nevertheless, this wealth of new information is edging Enceladus ahead of Europa in terms of where planetary scientists think that life might be found.

“I’m inclined to boost Enceladus higher than Europa now,” says Rothery. “It’s almost certainly habitable – we just don’t know whether it’s inhabited.”

For now, there are no further plans to send anything back to the Saturn-Enceladus system. Once the Cassini mission ends, however, and planetary scientists start to really digest the new information, the chances are that a follow-on astrobiology-oriented mission will begin to gather support.



The blotches on this false-colour images of Titan are thought to be lakes of liquid methane and ethane

# Titan

**Parent planet: Saturn**

**Orbital period: 15.945 days**

**Radius: 0.404 Earth radii**

**Mass: 0.0225 Earth mass**

**Planetary Habitability Index: 0.64**

THIS MOON OF Saturn is an altogether more alien place, sitting under obscuring clouds that are rich in organic molecules. Its surface was revealed by ESA's Huygens lander that parachuted down in 2005. During the descent, the craft made some intriguing electrical measurements. Combined with measurements of the way the moon's gravitational field differs from place to place, they strongly suggest of an ocean beneath the surface.



With all the organic molecules in the atmosphere and on the surface of Titan, there's a strong chance the ocean would be full of them too, increasing the chances of life. But could we sample this ocean to test that hypothesis?

"That's the question," says Lunine. "There's nothing spewing out of that ocean onto the surface of Titan."

But maybe we don't need to go deep to find life on this particular moon. There is liquid on the moon's surface,

but it's not water. Liquid methane and ethane pool in lakes and seas at the moon's polar regions, the largest of which is about the size of the Caspian Sea on Earth. Could life be based on methane rather than water?

Lunine thinks so. Together with some chemical engineering colleagues, he found a theoretical biochemistry that could work for methane, but testing it is going to be extremely hard. "It's very hard to 'cook up' biochemistry in the lab," he says, "It's probably easier just to go to these places and look. It would be interesting to land on one of Titan's seas and see what's going on."

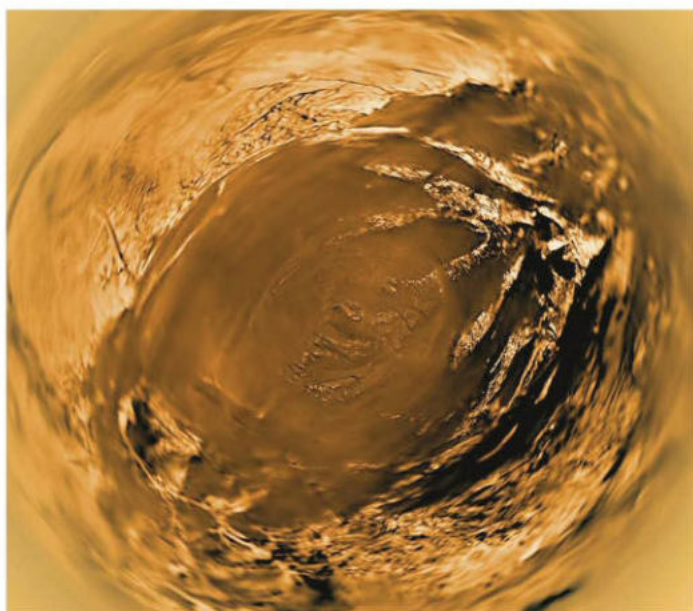


PHOTO: NASA X2, ESO

An aerial view of the surface of Titan, captured by ESA's Huygens lander in 2005. Data sent back by the Cassini-Huygens mission remains our primary source of knowledge about this moon



# Exomoons

OCTOBER 2015 MARKED the 20th anniversary of the discovery of 51 Pegasi b, the first planet to be discovered in orbit around a Sun-like star. It was a giant planet like Jupiter and was revealed because of the tiny 'wobble' it induced in its parent star. Since then, thousands more exoplanets have been discovered around stars in the Milky Way. Many are like Jupiter and Saturn, so it seems likely that they would also have moons.

We may be able to detect such moons by studying their 'transits'. During a transit, a planet crosses the face of its parent star and blocks out some light. This drop in brightness can be measured to give the size of the planet, which is how NASA's Kepler space telescope found more than 1,000 planets from 2009-2013. Any moons around those planets will cause additional, smaller drops in light, so it should be possible to detect them with ultra-sensitive measurements. The SuperWASP (Wide Angle Search for Planets) has detected at least one tentative transit signal that could be an exomoon, and next-generation space missions such as ESA's CHEOPS (2017), NASA's TESS (2018) and ESA's Plato (2024) also stand a chance of detecting exomoons in this way.

Many of these moons will be found around giant planets that are much closer to their parent stars than Jupiter and Saturn. That means receiving more heat, so oceans on those moons will not be underground. Starlight will melt the ice, turning the moon into a water world where life could flourish. But the habitat is unlikely to be long-lived: the weak gravity of a small moon will not be able to prevent the atmosphere being eroded by the fierce starlight. The exomoon will resemble a giant comet, with a gassy tail stretching into space, and will eventually become a tiny rocky cinder. Not ideal. But good while it lasted. ■

DR STUART CLARK is author of several books including *The Unknown Universe*

## DISCOVER MORE!



Learn more about all aspects of space science by watching *Stargazing Live* on 12-14 January.

**"It's very hard to 'cook up' biochemistry in the lab. It's probably easier just to go to these places and look"**

Jonathan Lunine, Cornell University



# ACTIVATE 'CHEAT MODE'

What did Volkswagen do when its cars didn't meet emissions standards? It decided to cheat. **Duncan Geere** investigates the scandal and finds out whether we could ever clean up the air in our cities...

**J**UST IN CASE you've been living under a rock for the last few months: the entire automotive industry is in the middle of its worst environmental scandal in decades. Volkswagen has been caught systematically cheating on emissions tests, while many more car manufacturers have faced similar accusations, with tens of millions of vehicles affected all over the world. But how dangerous are the pollutants involved? Who's to blame for ineffective testing? And how much can we trust companies to tell us the truth about the cars that we drive?

The whole mess began on 18 September 2015, when the United States Environmental Protection Agency (EPA) publicly accused Volkswagen of using carefully-designed software to circumvent diesel emissions testing.

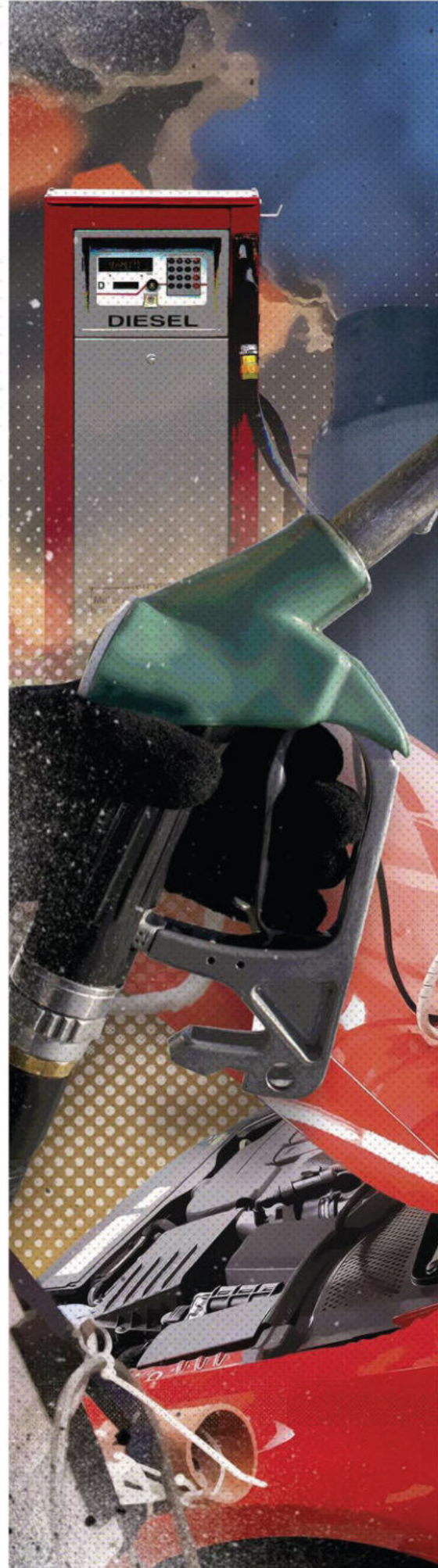
"A sophisticated software algorithm on certain Volkswagen vehicles detects when the car is undergoing official emissions

testing, and turns full emissions controls on only during the test," EPA wrote in a damning report. "This results in cars that meet emissions standards in the laboratory or testing station, but during normal operation emit nitrogen oxides, or NOx, at up to 40 times the standard."

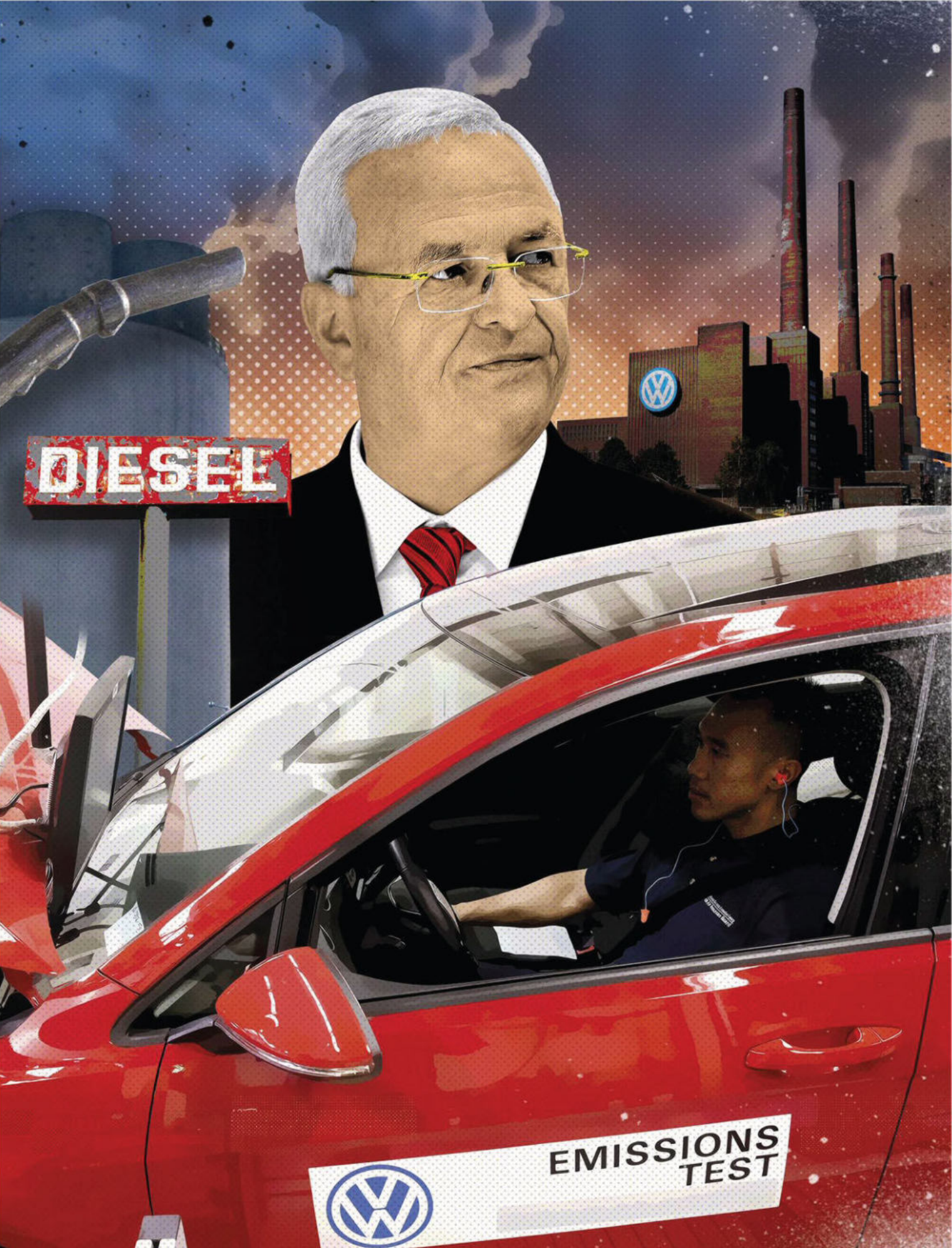
## WHAT A STINKER

Traditional emissions tests work by putting cars onto a stationary test rig in controlled laboratory conditions, where speed, engine operation, air pressure and even the position of the steering wheel are defined in advance. Volkswagen's device supposedly monitored for those conditions and when it detected them it would ramp up its emissions-scrubbing system into overdrive to comply with the test's requirements. When the test was over, the cars would go back to belching out air pollution in vast quantities again.

The requirements for NOx emissions differ around the world,









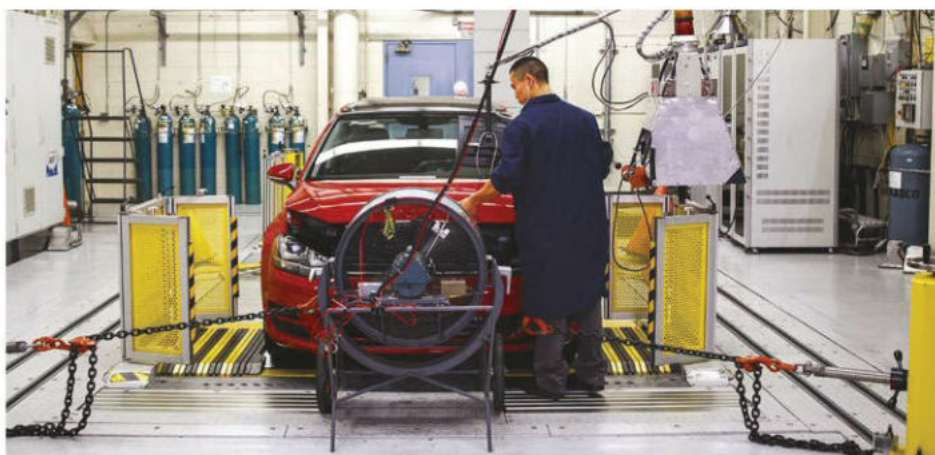


→ and depend upon the type and age of the vehicle. In Europe, the newest diesel cars are subject to the Euro 6 emissions standard, which was introduced in 2015 and allows just 80 milligrams of NOx to be emitted per kilometre driven. That's substantially less than the previous Euro 5 standard, which permitted 180 milligrams per kilometre.

Unfortunately, the laws of physics mean that the temperatures and pressures at which a diesel engine runs most efficiently and delivers the most energy also happens to be the conditions that convert the maximum amount of oxygen and nitrogen into NOx. That means that building one is a trade-off between power, fuel efficiency and clean emissions. To sell more of their cars, manufacturers like to boost the first two, but to be allowed to sell cars they have to allow for the third.

### CLEAN IT UP

Catalytic converters only work in petrol cars, but there are similar technologies available for diesel. Mercedes-Benz cars inject a fluid called urea that converts NOx into less harmful substances, but the tank of fluid has to be periodically refilled. Volkswagen instead invested in a sponge-like technology that soaks up the polluting gases – details on how it works are sketchy, but it's thought that when activated this filter lowers engine performance. That, it seems, may be why



Volkswagen cars emitted lower NOx levels during tests, then went back to belching out higher amounts when the test was over

the company decided to cheat.

It is, however, relatively simple to fix the cars. A software update is all that's needed, which reactivates the filter. Volkswagen says that about 11 million cars worldwide, including 8.5 million in Europe, are affected and must be recalled to apply the fix. Making things right is costing the company about £4.8bn, and that's before fines from regulators and legal action are taken into account. Unsurprisingly, the company's shares have fallen by almost a third since the news broke.

The news that Volkswagen had been cheating in the tests didn't come as a surprise to Dr James Tate, a lecturer at the Institute for Transport Studies

**“Since 2011 we've been publishing results showing that diesel cars in real driving were emitting high amounts of nitrogen oxides”**

James Tate, University of Leeds







Protesters at the Volkswagen plant in November 2015



Matthias Müller was appointed as new VW CEO in September 2015

## What are nitrogen oxides and how do they affect the environment and human health?

NITROGEN OXIDES, ALSO known as NO<sub>x</sub>, are a family of gases produced during high-temperature combustion in air. Before humans came along, that meant forest fires and lightning bolts, but since the Industrial Revolution spread millions of combustion engines around the planet, the amount of NO<sub>x</sub> in the atmosphere has increased dramatically. Cars, power plants and planes all produce them in large quantities, with the result that air pollution is responsible for one in eight deaths around the world.

Unlike carbon dioxide, NO<sub>x</sub> gases don't last too long in the atmosphere – only a matter of hours. But that's because they react with other gases to form even more noxious substances. They react with ammonia, moisture and other compounds to form nitric acid vapour, which can damage sensitive lung tissue and cause conditions like emphysema and bronchitis.

They also react with another by-product of combustion – volatile organic compounds – to create ozone. When ozone is up in the stratosphere, 10km above the ground, it's great. It protects us from ultraviolet radiation, and that layer of stratospheric ozone is crucial to life being able to exist on Earth. Near the Earth's surface, though, ozone hangs around for longer than NO<sub>x</sub> does, meaning that it can cause health impacts – such as lung damage – far from the source.

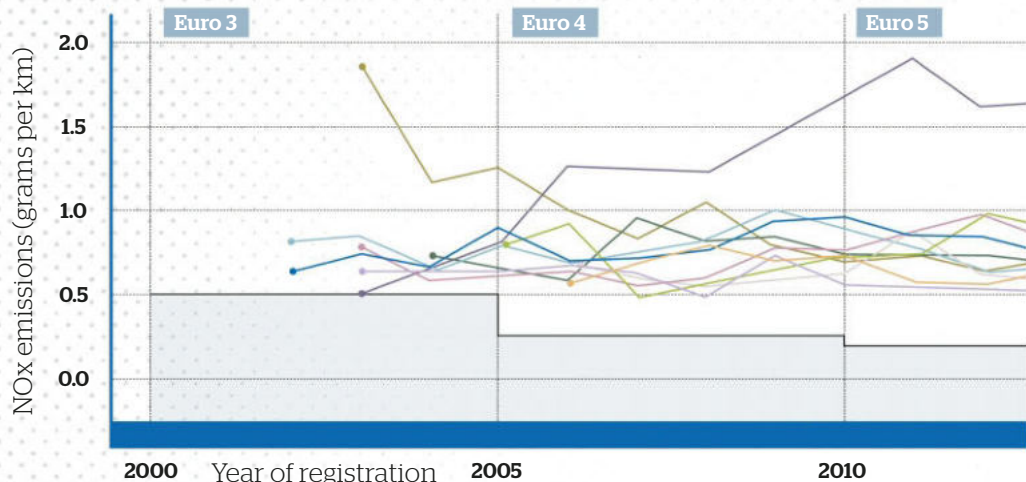
Finally, NO<sub>x</sub> gases react with a variety of common organic chemicals to form toxic products like nitroarenes, nitrosamines and the nitrate radical – which can cause biological mutations. That's why you rarely see moss and lichens on trees near city roads – they can't cope with the gases emitted by car engines.



## GRAPHICAL ANALYSIS

According to analysis by the Institute for Transport Studies, cars have not been meeting the emissions standards set by Europe outside the test lab. However, overall emissions from various sources appear to be falling and the growth of alternative fuels may help improve this further

NO<sub>x</sub> emissions by manufacturer and year of first registration



at the University of Leeds. For years, he's been collecting data on the emissions of every car on the road. "Since 2011 we've been publishing results showing that diesel cars in real driving were emitting high amounts of nitrogen oxides," he says.

His methodology is dramatically different to the official tests. It involves setting up a 'sensing beam' across a major road. "When vehicles drive through it, it makes a measurement of each individual vehicle," he explains. "Then we record the number plate of the vehicle, the vehicle's speed and acceleration, and we cross-reference the number plate to the vehicle registration database in the UK."

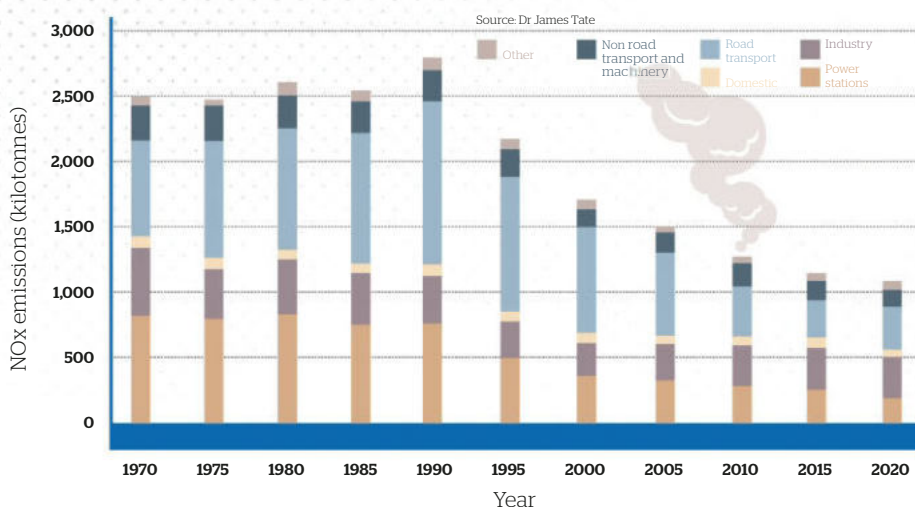
By the end of 2015, he'd collected data on as many as 70,000 individual cars, allowing him to generate statistically-rigorous averages of real-world emissions data on all of the most popular models of car out there. His results show that it's not just Volkswagen failing to meet the emissions standards under real-world conditions. "Basically, you see that all manufacturers are at a staggeringly similar level. Very similar," he says. "It's very easy to collect an awful lot of driving information. The [European] test is hideously out of date, and ineffective."

## CHOKING PROBLEM

Prof Håkan Pleijel at the University of Gothenburg is a specialist in the effects of air pollution on vegetation. He agrees that the test needs revamping. "These test cycles don't really correspond to the way the engine would work when it's out driving in the city," he says. "There is space for improvement in terms of using more realistic test cycles or testing the cars actually driving in ordinary traffic."

The obvious result of this flawed testing methodology means that there's far more pollution being emitted than we

NO<sub>x</sub> emissions by source



**"NO<sub>x</sub> levels have declined to some extent in Europe. But in some cases the decline does not match the expected emission reductions"**

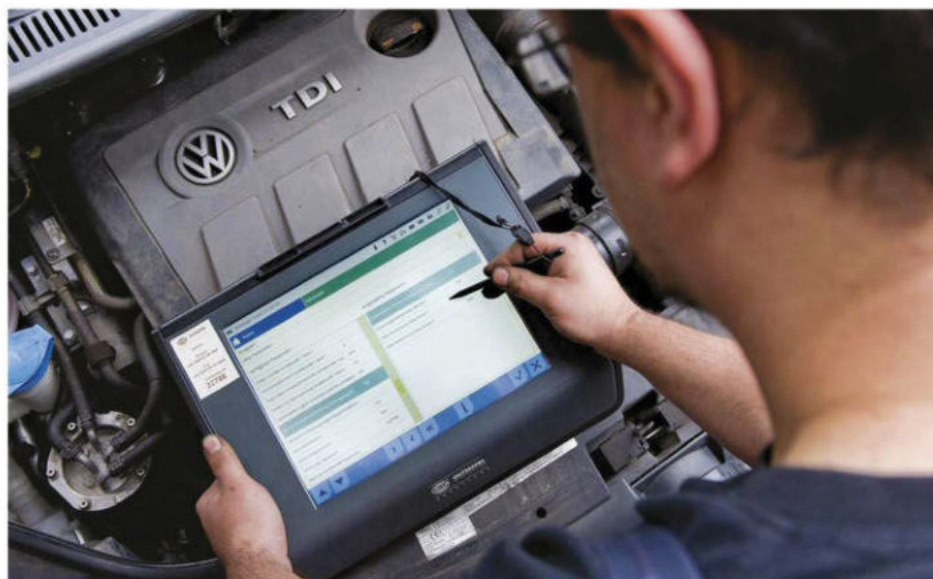
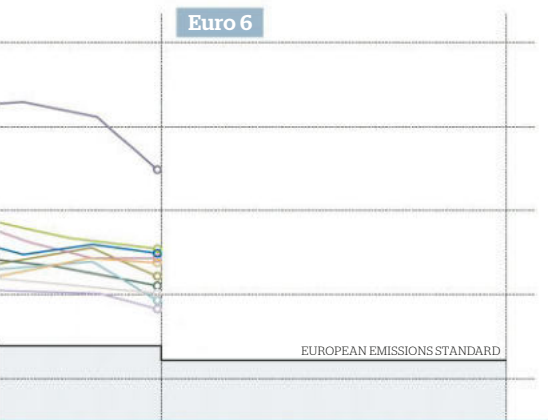
Prof Håkan Pleijel, University of Gothenburg

realise. "NO<sub>x</sub> levels have declined to some extent in Europe over the last few decades," says Pleijel. "But in some cases the decline does not match the expected emission reductions. It would be expected that the concentrations would have gone down a bit further."

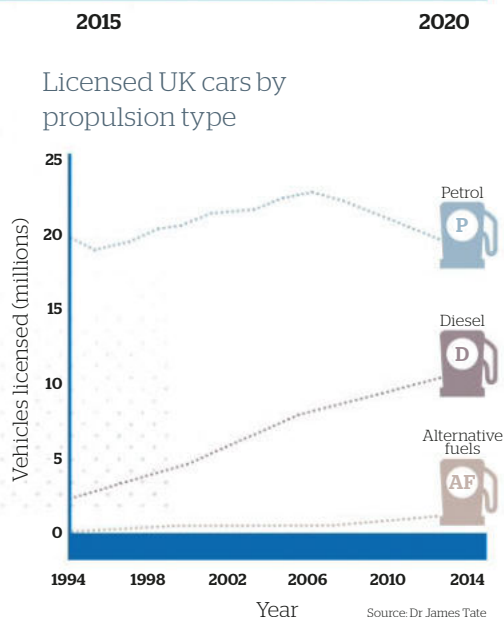
That's the reason why many European cities are failing to meet air quality standards. When the European Environment Agency (EEA) last published data in 2014, more than 95 per cent of the urban population was exposed to unsafe levels of certain pollutants. "That leads to high costs," explained Hans Bruyninckx, EEA's Executive Director, at the time. "For our natural systems, our economy, the productivity of



Source: Dr James Tate



A readout device measuring the emissions for a Volkswagen Touran



City authorities could help crack down on emissions on their streets

Europe's workforce, and most seriously, the general health of Europeans."

While researchers have known for several years that emissions laws weren't resulting in the kinds of drops that should be expected, VW's admission energised the public debate over air pollution, with far greater public scrutiny on vehicle emissions. "We've had 10 times more interest since VW have owned up to being fraudulent," says Tate.

But will that translate into long-term change, and perhaps even the end of diesel as a fuel, or will we be back to business as usual within a year? "There will be some small effect but probably not a big one," says Tate. "The thing that could make a big difference is what city

authorities can do. The motor industry, whilst it has the lobbying power to influence the European Commission, has it got the lobbying power to go around all the major cities?"

Pleijel is similarly pessimistic, and adds that there could be unanticipated consequences if people lose trust in environmental data. "This is very important, because it could have side effects outside VW and the associated trademarks," he says. "Customers may become reluctant to pay extra for the environment, because they don't want to be cheated."

For VW, the priority is getting trust back. "Volkswagen must put up a convincing performance in every respect

over the coming years – with customers, dealers, investors and authorities," VW's Paul Buckett tells us. "That is the only way we can win back trust. It will be a long, difficult road. We do not underestimate the magnitude of this challenge." ■

**DUNCAN GEERE** is a freelance science and technology journalist, based in Gothenburg

## DISCOVER MORE!



To listen to an episode of *Costing The Earth* that asks whether we've been lied to about air quality, visit [bbc.in/1FGghlu](http://bbc.in/1FGghlu)



# IT'S A SMALL WORLD

Since 1975, the annual Nikon Small World competition has celebrated the art and science of photomicrography – taking pictures through a microscope. 2015's winners were announced in October, and the top 20 images chosen by the judges will now go on a tour of museums and science centres worldwide. Here, we present *Focus's* own selection of some of this year's most striking images...

WORDS: CATHERINE E OFFORD





# ANIMAL

## ↓ GRUB'S UP

**Mites on an insect pupa, 20x**

These beady-eyed little critters tucking into their dinner are mites. The meal and the surface they're standing on is the body of a luckless pupa (the intermediate developmental stage between a caterpillar and a butterfly). There are estimated to be nearly 50,000 species of mite in the world, a large proportion of which are parasites that live on other animals or plants.

**Rogelio Moreno Gill, Panama**



## ↓ A REAL EYEFUL

**Eye of a honey bee covered in dandelion pollen, 120x**

This year's competition winner shows the complex eye of a western honey bee (*Apis mellifera*), dusted in yellow specks of pollen from a dandelion. Each black segment on the surface is one of thousands of tiny, lensed units that make up the bee's compound eye. One eye unit supplies a small section of the whole image that the bee sees. This photo took four hours to set up and shoot.

**Ralph Claus Grimm, Queensland, Australia**



## ← SMILE

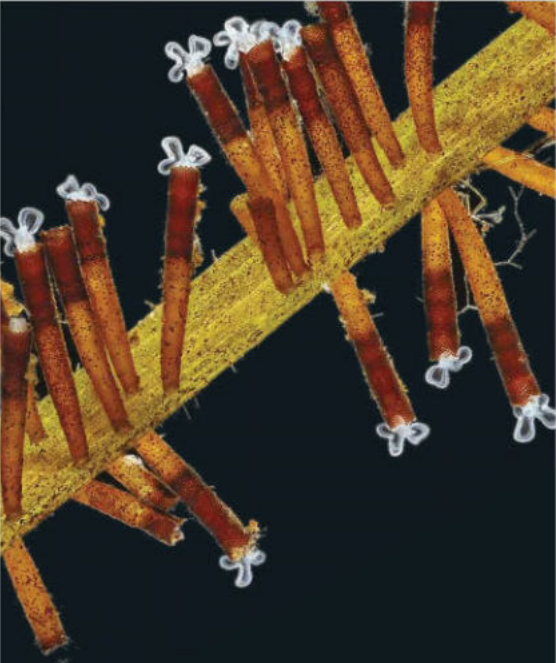
**Jaws of a long-jawed spider, 10x**

This charming face belongs to a long-jawed orb weaver spider. Spiders like this one build webs near water and hang motionless in them, waiting to trap unfortunate insects. The jaws, scientifically known as chelicerae, are used to inject paralyzing venom into their prey, which also partially digests it before the spider sucks up the soupy mess.

**Geir Drange, Asker, Norway**







## ↑ DOWN THE TUBE

Feeding *Floscularia ringens*, 50x

Each set of ear-like white loops in this image is in fact the protruding head of a single *Floscularia ringens*. More commonly known as rotifers, these bizarre, aquatic animals measure less than one millimetre in length. The tiny creatures build protective tubes – the dark orange rods in this image – using debris compressed into brick-like pellets laid one upon the other. Anchored to an underwater plant by its tube, each rotifer feeds by beating the white loops on its head, which are made of hair to propel food into its mouth.

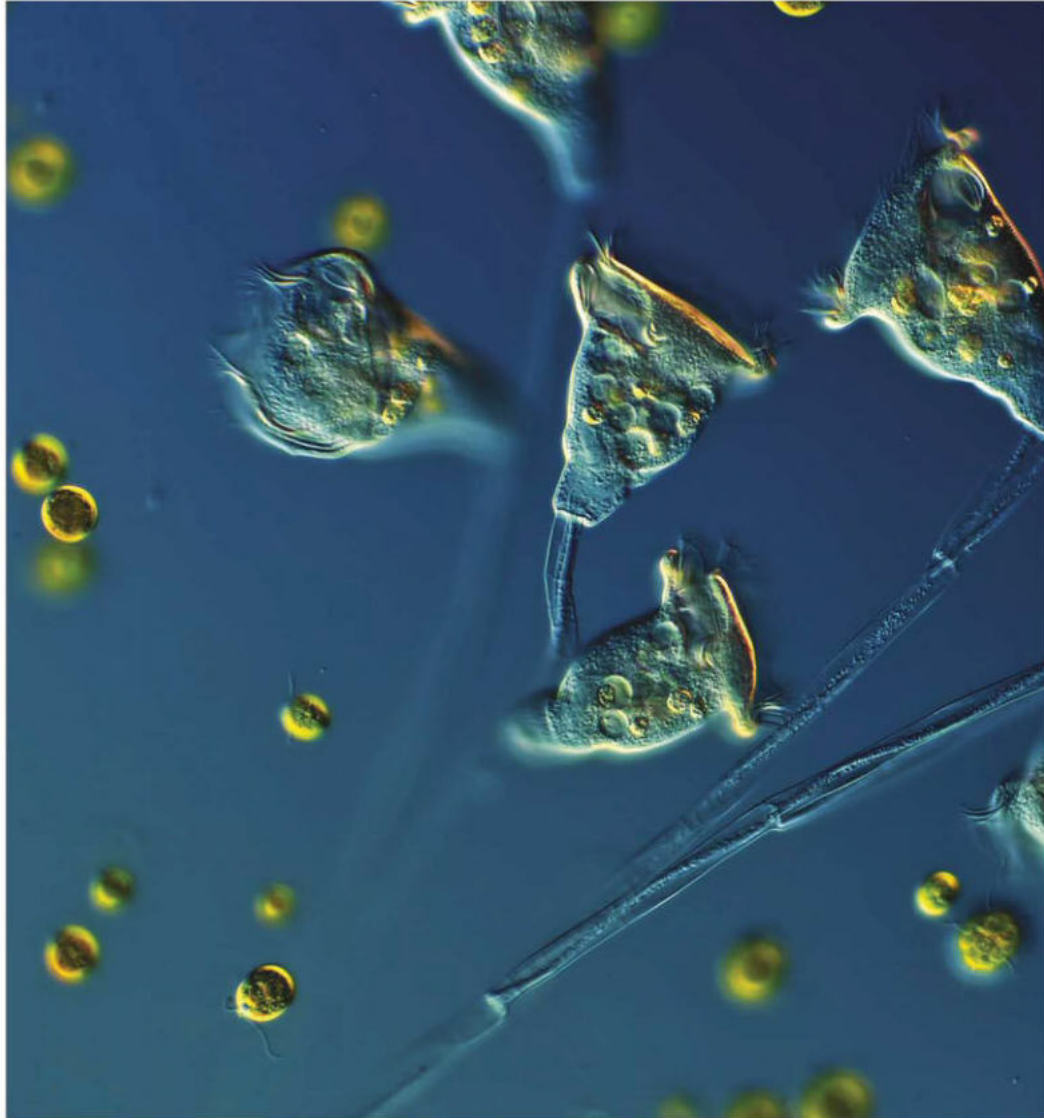
Charles B Krebs, Washington, USA

## SHOW YOUR GUTS ↘

Living rotifer (*Synchaeta*), 400x

Meet one of the world's weirdest animals: the rotifer. While some rotifers live relatively stationary lives (see above), the one seen here is a free-swimming species, measuring about half a millimetre long and often found milling around rock pools. A crown of tiny hairs called cilia beat to move it gracefully through the water. Although the animal is transparent, it often contains colourful patches – such as the green blobs in this image – as a result of bits of plants and other food making their way through its digestive system.

Dr Bernd Walz, University of Potsdam, Germany



# M I C R O B E S

## HAIRY HORNS AND TINY TREES ↑

Colony of *Carchesium ciliates*, 160x

Each of these little 'horns' is one *Carchesium* ciliate, a protozoan cell that lives underwater in colonies made up of hundreds of individuals. Every cell is attached to the colony's base by a long stalk, giving the colony a tree-like appearance. The stalks can retract independently to protect the ciliates if the surrounding water is disturbed. In this image, the stalks are extended for feeding, while hairs around the mouth of each 'horns' – too small to see even in this microscopic image – beat back and forth to pull in food.

Arturo Agostino, Reggio Calabria, Italy, 160x

## BLUE RIBBANDS GLOW RED →

Blue-green cyanobacteria showing auto fluorescence, 400x

This image shows string-like cells of a blue-green cyanobacteria called nostoc, glowing with fluorescent pigmentation. The red colour comes from chlorophylls – chemicals that absorb light to be converted to usable energy. Cyanobacteria are found all over the planet and have been considered for many potential applications, from renewable electricity generation to food production for humans on Mars.

Dr Kesara Ananthawat-Jonsson, Andrey Gagunashvili and Ólafur S Andrússon, University of Iceland, Reykjavik, Iceland



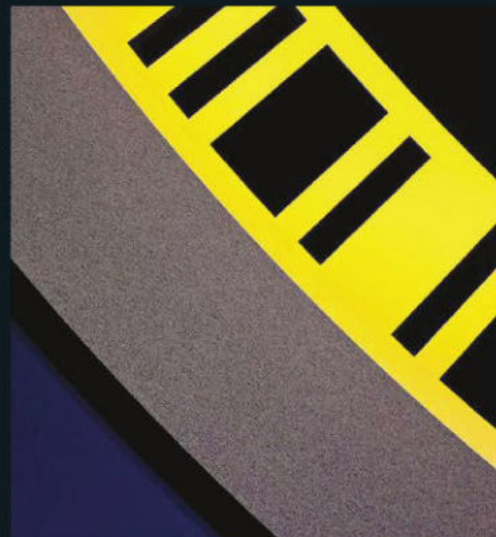
# MINERALS

## BAND OF CODE →

**Numerical traces on a Blu-ray disc, 100x**

High magnification disguises a familiar object in this abstract artwork. The black and yellow bands in this image come from a Blu-ray disc, where they act along with an alphanumeric key (not shown) as a unique barcode, allowing distributors to identify individual copies of a disc. The 'blu' section of the Blu-ray contains the data, such as the movie stored on the disc. The striking colours in this image were achieved with angled lighting using optical fibres.

**Massimo Brizzi, Empoli, Italy**

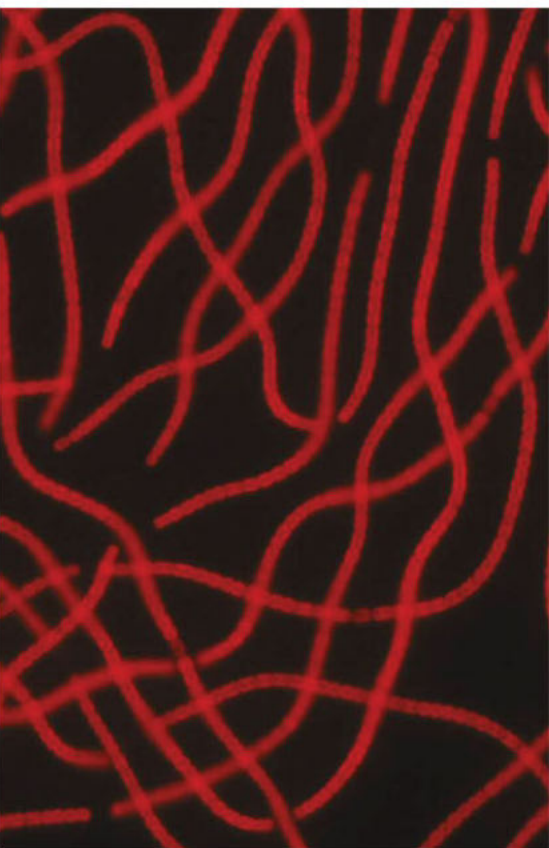
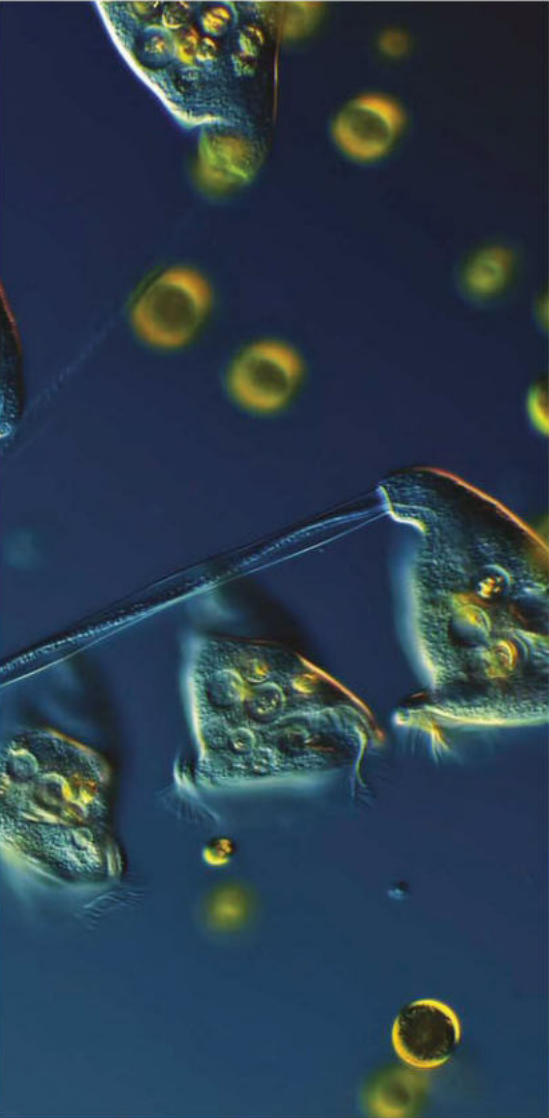


## SHOOTING STARS ↓

**Twinned crystals of 4,4'-dibromobiphenyl, 25x**

This otherworldly scene shows tiny crystals of a chemical known as dibromobiphenyl. Here, molecules of the substance have spontaneously self-organised into regular star patterns, coloured in this image using polarised light. The brominated biphenyl group of chemicals to which dibromobiphenyl belongs were once used widely in flame retardants, pesticides and plastic manufacturing. These days, however, its commercial use is limited due to uncertainty surrounding the health risks associated with it.

**Dr Ryoji Tanaka, Kanagawa, Japan**







## GEMSTONE TERRINE ↓

### Fairburn agate from the Black Hills of South Dakota, 63x

The orange bands in this image are from Fairburn agate, a gemstone made of silica (silicon and oxygen). Named after a small town in South Dakota where it is commonly found, the stone is richly coloured by impurities in the rock. Rusty oranges like this are often caused by iron oxides. The largest intact specimens weigh over 20kg and the stone is so popular among collectors that South Dakota named Fairburn agate its 'state gemstone' in 1966.

**Douglas Moore, University of Wisconsin, Wisconsin, USA**



## CRYSTAL FINGERPRINT ↘

### Chiral thermotropic liquid crystal, 20x

This image shows not an aerial view of the world's most fiendish hedge maze, but the spiralling patterns formed by a liquid crystal. Crystals like this one are said to be 'thermotropic' – that is, they only exist within a certain range of temperatures. Too cold and the mixture forms a glass-like solid. Too hot and the delicate structures break down. Here, the temperature of the crystal is just right, causing it to form arms and threads that spiral around each other in mind-bending patterns.

**Dr Giuliano Zanchetta, Dept of Medical Biotechnology, University of Milan, Italy**

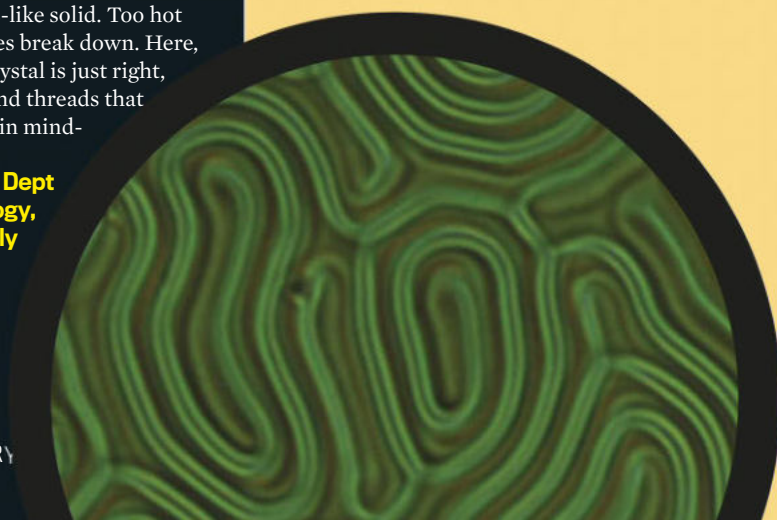
# PLANTS

## RELEASE THE SPORES ↑

### Spore capsule of a moss, magnification unspecified

Behold the biological storage solution of a *Bryum* moss. This 'capsule' sits atop a long stalk that raises it above the rest of the ground-hugging plant. When the time is right (that is, when the air isn't too wet), the tentacle-like canopy retracts to release thousands of reproductive spores stored in the capsule. The spores are dispersed through the air by the wind and those that land in damp, favourable soil will go on to make new mosses.

**Henri Koskinen, Helsinki, Finland**





## STICKY FINGERS ↓

### Tentacles of the *Drosera*, 20x

It might look harmless, but this leaf could mean a rather sticky end for an unfortunate fly. The glistening rods in this photo belong to a member of the carnivorous plant genus *Drosera*, commonly known as sundews. These plants feed on flies and other insects that become caught in the sticky droplets at the tips of hundreds of tentacles growing from their leaves. The tentacles are extremely sensitive and can bend to bring trapped insects closer to the leaf as they're slowly digested, after which the nutrients are distributed through the rest of the plant.

José Almodóvar, Biology Department, University of Puerto Rico, USA







## PEERING OUT ↑

**Vascular bundles of *Cyperus papyrus*, 200x**

These creepy little faces pop out of the cross-section of a papyrus plant, popularly known for its use as a source of paper in Ancient Egypt. Some plant cells in this image have been lit in pink using a microscopic imaging technique known as 'differential interference contrast', which uses polarised light to exaggerate small differences in lighting and colour in transparent objects. Each 'face' outlines a plumbing feature known as a vascular bundle, present in most terrestrial plants, which carries water and nutrients around the roots, stems and leaves.

**Dr David Maitland, Feltwell, United Kingdom**

## CRAZY PAVING →

**Transverse section of an ostrich fern, 250x**

Each 'tile' in this vivid mosaic is a cross-section of a plant cell belonging to an ostrich fern, also known as a fiddlehead or shuttlecock fern. Each of its descriptive names reflect the fern's distinctive upright posture and feather-like fronds. The cells featured in this image transport water and nutrients around the fern, and are common to almost all plants that grow on land. Unlike flowering plants and conifers, however, which organise these cells into regular clusters called 'bundles', ferns have stuck with the slightly more freeform arrangement shown here.

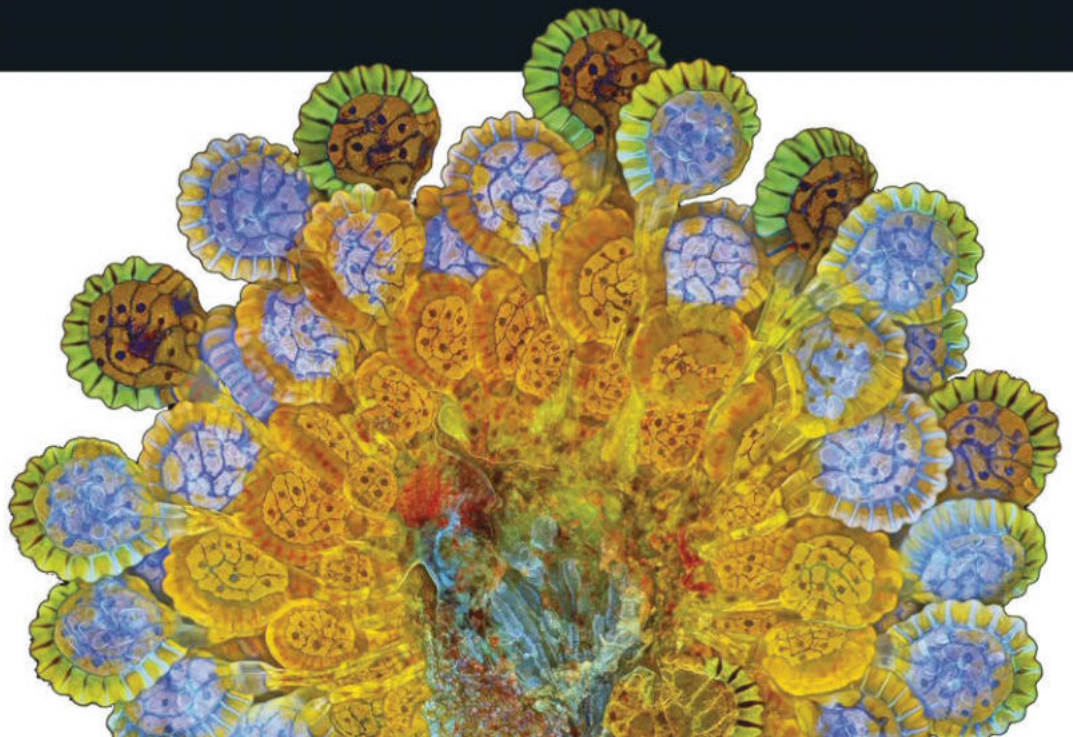
**Anatoly Mikhaltsov, Omsk, Russia**

## LEAF MANDALA →

**Sorus fern, 20x**

This colourful fan is a sorus, a structure found on the underside of fern leaves. Each panel in the fan is a spore-containing 'sporangium', which releases spores into the wind to be dispersed and emits a fluorescent glow when lit by high-intensity UV light. The specific colouring of each section depends on the developmental stage (age) of the sporangium, accounting for the rich colour palette seen in this image.

**Rogelio Moreno Gill, Panama**









# THE UNIVERSE: THE STORY SO FAR

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# Q&A

## YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



**SUSAN BLACKMORE**

Susan is Visiting Professor at the University of Plymouth. Her books include *The Meme Machine* and *Ten Zen Questions*



**DR ALASTAIR GUNN**

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



**ROBERT MATTHEWS**

After studying physics at Oxford, Robert became a science writer. He's Visiting Professor in Science at Aston University



**GARETH MITCHELL**

Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service



**LUIS VILLAZON**

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO [questions@sciencefocus.com](mailto:questions@sciencefocus.com)

or post to *Focus Q&A*, 2nd Floor, Tower House, Fairfax Street, Bristol, BS1 3BN



In China, fireworks were traditionally used to scare off evil spirits

**Q** MATT STRINGER, ST ALBANS

### How are the colours and shapes of fireworks created?

**A** DESPITE BEING INVENTED in China almost 1,000 years ago, fireworks involve some pretty sophisticated science. The spectacular colours are the result of metal compounds combining with oxidisers that supply oxygen. This produces heat, which kicks electrons in the chemicals into higher energy levels. They rapidly return to their normal 'ground state', and shed the

energy as light. Relatively cool-burning strontium carbonate gives red, sodium nitrate produces yellow, and barium chloride gives green. The hardest colour to produce is an intense blue, which needs the firework to reach a high temperature, but not so high that it simply burns up. Manufacturers often use copper chloride to hit the right temperature range and achieve a bright, rich blue.

The spectacular shapes are produced by embedding the packets containing the colour-making chemicals – known as 'stars' – in gunpowder, together with a burst charge. Once the firework reaches the right altitude, the burst charge explodes, detonating the gunpowder, and blasting the stars out into the pre-arranged pattern. **RM**

PHOTO: GETTY



Q CURTIS MORTIMER, NORTHAMPTON

## Why can't everybody roll their tongues?



**A** SCIENTISTS AREN'T SURE. There is a long-standing myth that tongue rolling is controlled by a single gene, but this was based on a single piece of flawed research and was debunked as early as 1952.

Tongue rolling seems to be an ability that comes with practice, not something you are born with. The most likely explanation is that because tongue rolling isn't useful for speaking, whistling, talking, kissing or anything else apart from showing off at parties, some of us just never got around to mastering the skill. **LV**

Q RICHARD O'NEILL, GLASGOW

## Why do raindrops appear hexagonal on camera lenses?

**A** IT'S A MANIFESTATION of an optical phenomenon called bokeh, which is Japanese for the effect of camera equipment on out-of-focus images. In the case of raindrops, it's a result of the blades of the camera diaphragm creating a polygonal-shaped aperture. The exact shape varies on the vintage and type of the camera. **RM**



PHOTO: GETTY, ALAMY X2, ISTOCK X3, SCIENCE PHOTO LIBRARY

Q EDWARD SEYMOUR, HOVE

## Are the oceans getting saltier?



The Dead Sea is about 10 times saltier than normal seawater

**A** SEAWATER TASTES SALTY because of the action of rain on exposed rocks. The compounds most likely to find their way into the sea are, naturally enough, the most water-soluble ones, and these are rich in chlorine and sodium ions – the raw ingredients for common salt. As this process has been operating for billions of years, there's no doubt oceans have got saltier over time. In fact, the real mystery is why they aren't now saturated with the stuff,

making them as lifeless as the Dead Sea. Somehow, the concentration has remains at just a few per cent for at least half a billion years. Exactly how isn't clear, but one theory, suggested by British ecologist James Lovelock, involves the vast, mat-like colonies of bacteria found in coastal lagoons around the world. The Sun's heat triggers evaporation of the water, leaving its salt content trapped on the coast and unable to dissolve back into the sea. **RM**

Q RAVI TEJA, LONDON

## Why are people only attracted to certain other people?

**A** MEN TEND TO seek more short-term relationships and look for physical attractiveness. Women also seek good looking short-term mates, but for long-term partners they're more interested in resources, seeking a man who will provide for them and any children. There are trade-offs between looks and health, and the desire to find someone similar in education, religion, intelligence, and wanting a family. Few people are aware of these underlying reasons, yet the same effects have been measured in 37 cultures across six continents. As for sexual orientation, many genetic, hormonal and other effects contribute to people finding others of their own sex more attractive. **SB**

Attraction is a trade-off between looks, health and similar beliefs... how romantic

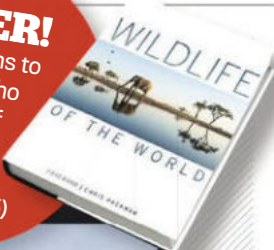




## QUESTION OF THE MONTH

**WINNER!**

Congratulations to Paul Leslie who wins a copy of *Wildlife Of The World* (Dorling Kindersley, £25)



Time travelling humans could come face-to-face with the predatory *Dimetrodon*... better hone those sprinting skills

**Q** PAUL LESLIE, CHELMSFORD

## Could a modern human survive on pre-dinosaur Earth?

**A** IT WOULDN'T BE easy. The Permian period, just before the dinosaurs appeared, ran from about 300 to 250 million years ago. The drifting continental plates had clumped all the land together into one supercontinent called Pangaea. The huge size and limited coastline made the interior of Pangaea a hot desert, while the south was frozen under ice caps. The north was only slightly better, with a hot climate and huge seasonal variations from wet to dry. Flowering plants had only just started to appear and almost all the food crops we eat today hadn't evolved yet. We would be restricted to pine nuts and a few edible tubers. Most of our diet would probably consist of insects, but 90 per cent of all insects at the start of

the Permian were varieties of cockroach, so that's hardly an attractive prospect.

More importantly, we would still need to worry about being eaten ourselves. Just because the dinosaurs hadn't appeared yet, it doesn't mean there weren't large carnivores. *Dimetrodon* and other large crocodile-type animals were the top predators. Our intelligence and cooperation would help against these threats, but we would have to manage with primitive weaponry. The plant matter laid down in the Carboniferous period wouldn't turn into coal for another 100 million years yet, so we would have to make do with peat and pine wood for fuel, which would make it difficult to get a fire hot enough to smelt iron with. **LV**

**Q** JAMES MALPAS, HISTON

## Why can't computers complete CAPTCHAs?

**A** ON A WEBSITE'S login page, CAPTCHAs are those obscure-looking characters we use to verify that we are human users and not bots. The characters are often distorted with the letters or numbers running into each other. Optical character recognition software struggles to pick out the individual forms, especially when their shape and size vary from one CAPTCHA to the next. **GM**

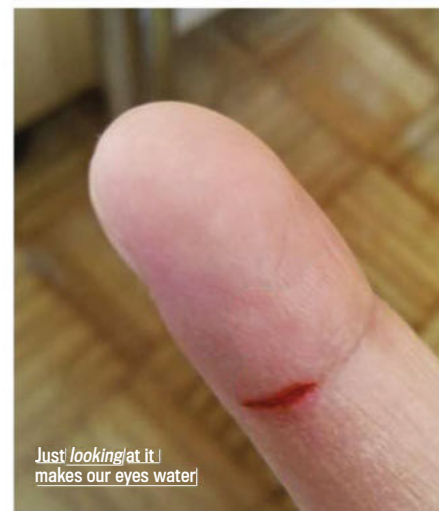


Common CAPTCHAs have only been around since 1997

**Q** RACHEL CATTINI, LONDON

## Why are paper cuts so painful?

**A** AT A MICROSCOPIC level, paper is actually quite rough. A metal knife makes a clean straight cut, but paper acts like a saw blade and does a lot more damage to cells and nerve endings. Paper also leaves behind tiny fibres and chemical residues, which irritate the wound even more. **LV**



Just looking at it makes our eyes water



## TOP 10

COLDEST PLACES  
ON EARTH

(by lowest recorded temperature)

**1. Dome Fuji, Antarctica**Temperature: -93.2°C  
When: August 2010**2. Vostok Research Station, Antarctica**Temperature: -89.2°C  
When: July 1983**3. Amundsen-Scott South Pole Station, Antarctica**Temperature: -82.8°C  
When: June 1982**4. Dome Argus, Antarctic Plateau**Temperature: -82.5°C  
When: July 2005**5. Mount McKinley, Alaska**Temperature: -73.8°C  
When: sometime between 1950 and 1969**6. Verkhoyansk, Russia**Temperature: -69.8°C  
When: February 1892**7. Klinck research station, Greenland**Temperature: -69.4°C  
When: December 1991**8. Oymyakon, Russia**Temperature: -67.8°C  
When: February 1933**9. North Ice, Greenland**Temperature: -66.1°C  
When: January 1954**10. Snag, Yukon, Canada**Temperature: -62.7°C  
When: February 1947

Q LAURENCE AGER, COULSDON

## How bright is daylight on Pluto?

**A** THE LIGHT FROM the Sun follows an 'inverse-square law'. So, if you're twice as far from the Sun as the Earth, for example, you'll receive one-quarter of the amount of light. Four times further away and you'll receive one-sixteenth the amount.

The average distance of Pluto from the Sun is about 39 times that of the Earth's. So, on average, the Sun on Pluto looks about 1,520 times fainter than it does on Earth. But this isn't

particularly faint. The full Moon is on average about 400,000 times fainter than the Sun. So, doing the maths, this means the Sun seen from Pluto is about 264 times brighter than the full Moon. This is about the amount of light you'd see on Earth when the Sun is around four degrees below the horizon, during 'civil twilight', which is more than enough to read by. Even on Pluto, looking directly at the Sun would probably be painful. **AG**



Pack your sunglasses for a holiday to Pluto

Q ANDREW GILL, CHRISTCHURCH

## Why do beached whales often die?

**A** DEATH IS OFTEN due to dehydration. Whales have an incredibly thick layer of insulating blubber. Without the water to keep them cool, they overheat and lose too much water via evaporation from their lungs. Whales can also drown as the tide comes in because they are lying on their

side and the water covers their blowhole before it's deep enough for them to swim free. Even if they do get back into the water, many whales die a few hours later because their huge weight causes crush injuries that release toxic breakdown products into their blood when the pressure is removed. **LV**





Q JAKE MELLOR, MANCHESTER

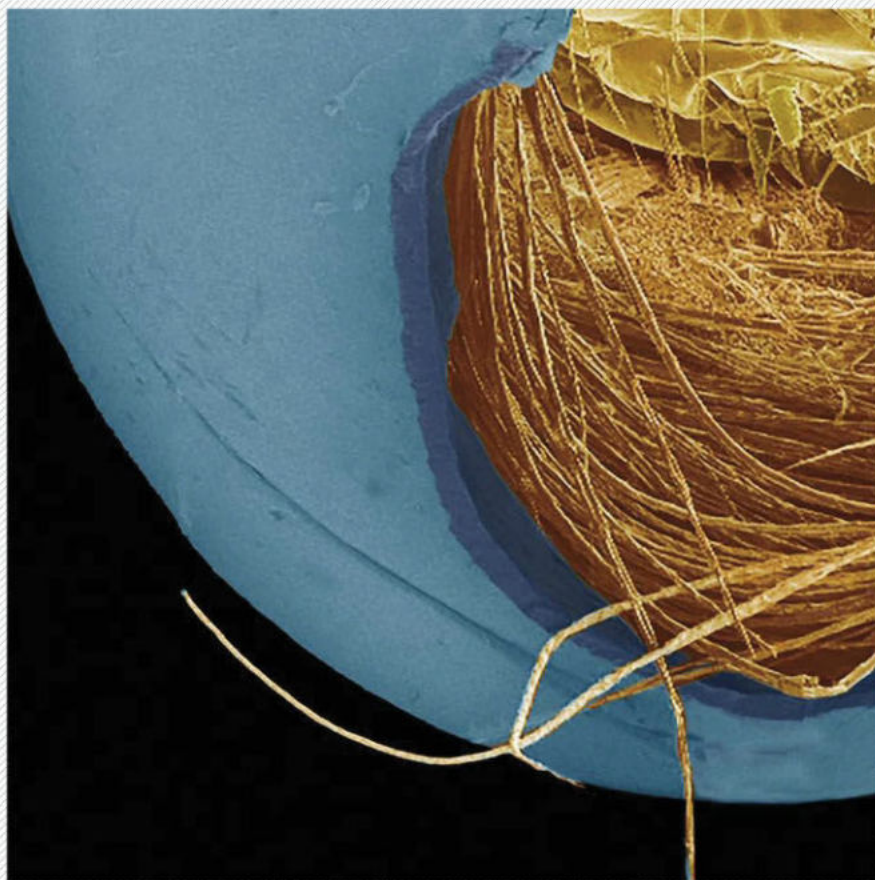
## Why do some people get allergies?

**A** ALLERGIES ARE CAUSED by an overactive immune system. There's evidence that this is inherited, but many studies have also shown that growing up in an excessively clean environment can trigger allergies. People from big families tend to have been exposed to more bacteria and have a lower chance of developing allergies. If you had skin cream containing peanut oil as a baby, you are more likely to be allergic to peanuts as an adult, and soy in formula milk may also trigger peanut allergies, perhaps because the proteins have similar molecular shapes. **LV**



On his days off from tormenting Batman, Bane loved to frolic among the flowers

### WHAT IS THIS?



**KNOW THE ANSWER?** Submit your guess now at [sciencefocus.com/qanda/what](http://sciencefocus.com/qanda/what)

Q EOGHAN LUMSDEN, DUBLIN

## Could we seed life on another planet?

**A** QUITE POSSIBLY – AND preventing it from happening has long been a key concern in interplanetary exploration. In 1964, the Committee on Space Research required that nations take care to sterilise space probes to minimise the risk of contamination by Earth-based organisms. As a result, probes are routinely treated with heat, radiation and disinfectants before launch. **RM**



Q ELLA SWANSON, COVENTRY

## Can you learn to like spicy food?

**A** THE HEAT IN chilli is caused by a chemical called capsaicin, which binds to the TRPV1 proteins in the nerves that sense pain and heat. If these receptors are continually stimulated by regular spicy meals then the nerve cells 'turn down the volume' by adding phosphate groups to the receptor proteins. This causes the protein to alter its three-dimensional shape and reduces its ability to bind to capsaicin, so you become less sensitive. Our sense of taste also naturally decreases as we get older, so food that used to be intolerably spicy might now produce just a pleasant tingle. **LV**





Q EMMA SMITH, PETERHEAD

## Why do we see shapes and colours when we rub our eyes?

**A** THESE SHAPES AND colours, called 'phosphenes', were reported as long ago as the time of the ancient Greeks. Rubbing your eyes increases the pressure within the eyeball and this pressure activates ganglion cells in the retina in the same way as light does. Your brain doesn't know the difference and so interprets the activation as though you were seeing light from the world outside. Most common phosphenes are diffuse blobs of different colours that move with the rubbing. Then there are scintillating and rapidly moving grid-like patterns which probably reflect the organisation of cells higher up in the visual system. These patterns are reminiscent of psychedelic paintings because the major hallucinogens also affect the visual system. Other effects include an array of intense blue points of light. If you want to experience these, be careful and press gently for some time rather than pressing too hard and risking damage to the eye. **SB**



All the effects of LSD without the health concerns!

### In Numbers

# 57%

of the 150,000 tree species in the Amazon could be at risk of extinction, if deforestation continues at its current rate

Q WILLIAM SIMONS, SOUTHAMPTON

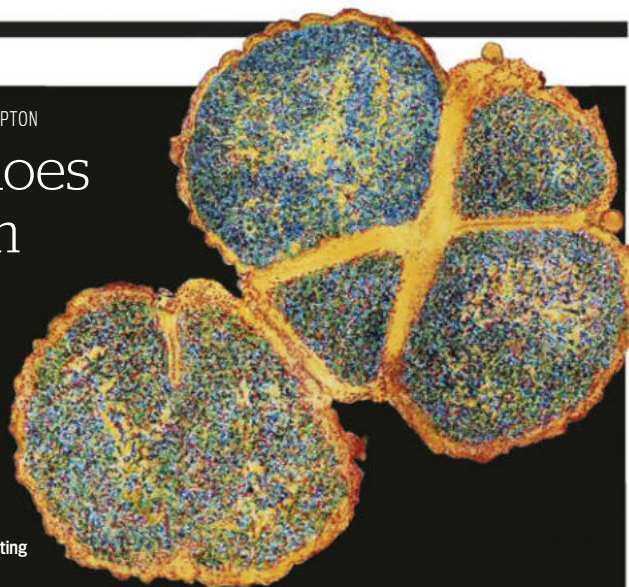
## Are many visible stars dead?

**A** PROBABLY NOT. ALL of the stars you can see with the unaided eye lie within about 4,000 light-years of Earth. But the most distant ones are intrinsically brighter, have more mass and are therefore likely to die in rare supernova explosions. We can only see fainter (and hence less massive) stars out to smaller distances and these stars are more likely to end their lives in less violent but more common deaths. This complicates the estimate of the 'death rate' for visible stars. But we can choose an intermediate distance, say 1,000 light-years, to estimate this number. Using our knowledge of the death rate in the entire Milky Way, the death rate for visible stars works out at about one star every 10,000 years or so. Given that all those stars are closer than 4,000 light-years, it is unlikely – though not impossible – that any of them are already dead. **AG**



Q TOM CRAWFURD, LITTLEHAMPTON

## How long does a bacterium live?



Bacteria splitting

**A** BACTERIA DON'T HAVE a fixed lifespan because they don't grow old. When bacteria reproduce, they split into two equal halves, and neither can be regarded as the parent or the child. You could say that so long as a single one of its descendants survives, the original bacterium does too. Individual bacteria can also turn themselves into spores with a tough coat to protect themselves from dry conditions.

Bacterial spores have been successfully revived from 250-million-year-old salt crystals found in New Mexico in 2000. But if we assume that the global bacteria population is stable, then it follows that one bacterium must die for each new one that is produced. Bacteria divide somewhere between once every 12 minutes and once every 24 hours. So the average lifespan of a bacterium is around 12 hours or so. **LV**





## Q Should we be naming our storms?

**Bill McGuire** wonders whether friendly monikers lessen the perceived impact of hurricanes



Hurricane Patricia: not as friendly as she sounds

HAVE YOU NOTICED how our weather is becoming humanised? Until recently, we might have noted in conversation: “bit windy last night.” Now we are more likely to hear something along the lines of: “took a bit of a battering from that Barney last night,” or “I blame Bruce Lee myself.” Not only does the current trend for naming extreme meteorological phenomena make discussions of the weather close to incomprehensible, it also makes the events sound friendlier and more cuddly.

### NAME GAME

This is a dangerous route to go down. Whether a storm is called Gertrude – the name awaiting the seventh storm of the UK winter – or is anonymous, it makes no difference to its capacity for devastation and loss of life. Worse, we might take fewer precautions if we are warned, not of imminent destructive winds, but of the arrival on our shores of Katie or Nigel. Take Patricia, for example. She might sound far too sensible to cause anyone any problems, but the reality was very different. Patricia was the most powerful hurricane ever recorded, and the most

intense western hemisphere storm of all time. In late October 2015, Patricia exploded from run-of-the-mill storm into a full-blown Category 5 hurricane. The core barometric pressure plunged to an astonishingly low 879 millibars, driving encircling winds that reached sustained speeds of a staggering 325km/h.

Patricia had the potential to cause massive devastation. Fortunately, she weakened rapidly as she approached western Mexico, and made landfall in a sparsely populated part of Jalisco state. A big sigh of relief following the reprieve has been replaced by growing concern over the possibility of a future Patricia ploughing into a densely populated region like Miami or New York.

### HEATING UP

As global temperatures climb, consensus holds that although overall storm numbers may not rise, the big ones will become more frequent. This applies equally to the events that are fed by the warm waters of tropical oceans, and to the broadly less powerful storms that periodically rampage across the UK and continental Europe during the autumn

and winter months. In fact, this seems to be happening already, with five of the seven most intense Pacific hurricanes making their appearance in the first 15 years of the new century. In the Atlantic the pattern also seems clear, with five of the 10 most intense hurricanes on record occurring since 2004.

### FIERCE FUTURE

An inkling of just how bad things might get is provided by 1979’s Typhoon Tip. As Tip meandered across the northwestern Pacific, winds peaked at 310km/h – just a little lower than those experienced during Patricia. Tip was a colossal storm with a diameter of more than 2,000km, but blew itself out before making landfall. A future nightmare scenario might involve increasing numbers of Typhoon Tips crashing into coastal cities at peak power. Whether such storms have cuddly names like Mildred or Maureen will make absolutely no difference to the devastation they wreak or the lives they take.

**BILL MCGUIRE** is Professor Emeritus in Geophysical & Climate Hazards at UCL



Q PIERCE BRADY, CORK, IRELAND

## Could there be stars and planets made from antimatter?

**A** IT IS A possibility. One of the greatest mysteries of modern physics is why the Universe is composed almost entirely of ordinary matter with only a tiny fraction of antimatter. The Big Bang should have produced the same amount of each. However, it has been suggested that different regions of the Universe could be dominated by one or the other, although how this might come about is also a mystery, and there is currently no evidence that this is the case. **AG**



Q STEVE TAYLER, COVENTRY

## Can facial recognition software differentiate between identical twins?

**A** IDENTICAL TWINS ARE a particularly stringent stress test for facial recognition systems. So when Windows 10 launched, some wondered whether twins could fool Windows Hello, the authentication feature that uses facial and iris recognition. An Australian newspaper tested it with six pairs of identical twins. Though hardly a scientific sample, the system did pass the test. This suggested that biometrics technology for consumers is clearing some big hurdles.

When it comes to identifying faces, humans are better at subjective judgments like whether someone looks happy, sad, angry or just a bit shifty. But computers beat us on the quantitative side of things such as measuring the relative dimensions of the features on a face. Windows Hello is built on Intel technology that combines a webcam, infrared camera and infrared laser projector. This three-pronged approach shores up the system's rigidity, even when confronted with identical twins. **GM**

Q WAIL ALSALLAMI, YEMEN

## What is the function of the golden foil that covers space probes?

**A** SOME PEOPLE THINK that the gold foil is there to block electromagnetic radiation and to protect the electronics on the spacecraft. But the function is actually thermal. Without the foil, heat would readily escape from the space probe into the coldness of space. In return, the Sun's heat would fry the equipment. The foil consists of several aluminium sheets, each contributing to better insulation. Sandwiched between the thin metal sheets is thermally opaque plastic spacer. **GM**



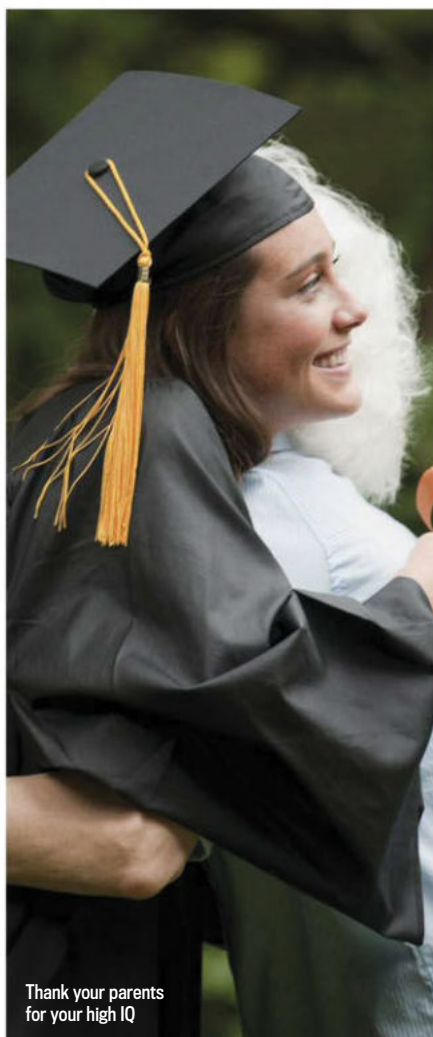


Q ALEX ROUND, LONDON

## Are academic traits genetic?

**A** YES. UNPOPULAR AS this is, the evidence has always shown high heritability of IQ, and IQ scores are closely correlated with academic performance, as well as occupation, health and income. One powerful method compares the abilities of identical and non-identical twins reared together or separately. The most recent conclusion from numerous such studies is that the heritability of intelligence rises from about 20 per cent in infancy to as much as 80 per cent in adulthood. This means that the majority of IQ differences between adults can be attributed to inheritance.

This effect may also be increased by 'assortative mating': the tendency of men and women to choose partners who are similar to themselves. Correlations between married couples are greater for intelligence than they are even for personality or height and weight, an effect that increases heritability. Clearly, upbringing, education, friends, health and many other factors influence academic success but genes play a very large part. **SB**



Q JOANNE MOORE, YORK

## Why is there an epidemic of short-sightedness in Asia?

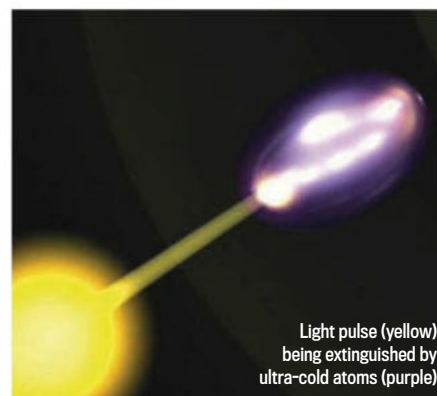
**A** IN CHINA, AROUND 90 per cent of young people are now affected with short-sightedness – a six-fold increase since the 1950s. In Seoul, 96.5 per cent of 19-year-old men are affected. The problem is also spreading worldwide. The cause is hotly debated, but attention is focusing on the lifestyle of 21st-Century children – specifically, getting too little exposure to daylight, which seems to influence eye development. **RM**



Q CHARLIE MACK, UCKFIELD

## Is it possible to trap light?

**A** PERHAPS THE MOST spectacular technique was perfected by Prof Lene Hau and colleagues at Harvard University. In 2007 they trapped light inside a cloud of ultra-cold sodium atoms, turned it into a pulse of atoms and then reversed the process – the light reappearing and moving off from its new location. **RM**

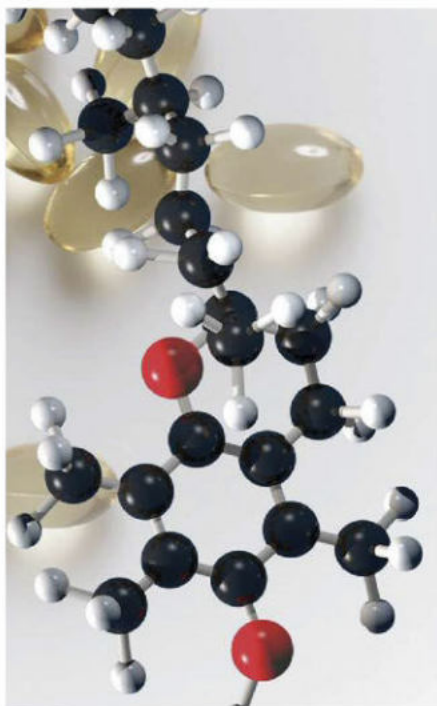


Light pulse (yellow) being extinguished by ultra-cold atoms (purple)

Q RICHARD MOORE, LIVERPOOL

## Which vitamin could you live the longest without?

**A** VITAMIN E. ADULTS only need 15mg a day and you'd get that from three tablespoons of sunflower or rapeseed oil, as well as lots of other common foods. The only people who normally suffer from vitamin E deficiency are those with another disorder, such as cystic fibrosis, that interferes with its absorption. Vitamin E is an antioxidant that protects your nerves and retinas from damage caused by free radicals. But even people born with a genetic disorder that prevents them from using vitamin E don't develop symptoms for at least the first four years. Although the disorder can cause blindness and muscle weakness, it isn't normally fatal. **LV**





Q SUSIE REES, LAMBERHURST

## What is worse for your mood – interrupted sleep or shortened sleep?



**A** INTERRUPTED SLEEP. AT least, that's what one recent study shows. We've long known that sleep deprivation makes people bad-tempered and miserable, and that insomnia is linked to depression, but exactly why is less certain. When volunteers slept in a lab and reported their mood every day, some were made to go to bed later than usual while others had their sleep interrupted several times. Both groups had the same total amount of sleep but the interrupted sleepers reported worse changes in mood.

The researchers concluded that a lack of slow-wave sleep, which is the deepest type of sleep, was to blame. But don't jump to conclusions. These interruptions may be like being woken by a crying baby or a snoring partner. They break into your sleep cycle unpredictably at random times, therefore disrupting the normal sleep pattern. But if you regularly wake up yourself in the night you are probably waking at the end of each cycle and this would not have the same detrimental effect on your slow-wave sleep. **SB**

Q LORELY MASKELL, BY EMAIL

## Why does plucking your eyebrows make you sneeze?

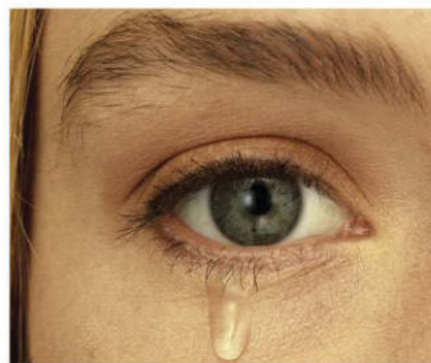
**A** A BRANCH of the trigeminal nerve extends around the eye and down to the nose. An ordinary sneeze is triggered by sensory signals sent from the nose along the trigeminal nerve. But the pain of plucking can cause a fake sneeze signal in nearby nerve endings. **LV**



Q JOHN RADFORD, HIGH WYCOMBE

## Why does sweat sting your eyes, but tears do not?

**A** TEARS AND SWEAT both have approximately the same salinity, but sweat contains oils and hormones that could irritate the eyes. The sweat that runs into your eyes has also run over your hair and forehead first, so it has had plenty of opportunity to pick up dust and grime along the way. **LV**



**NEXT MONTH** Over 20 more of your questions answered



For more answers to the most puzzling questions, see the Q&A archive at [sciencefocus.com/qanda](http://sciencefocus.com/qanda) or follow us on Twitter @sciencefocusQA



# NEW FROM **FOCUS**

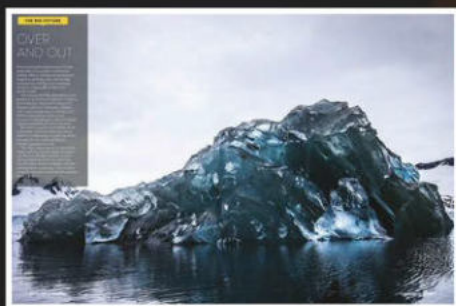
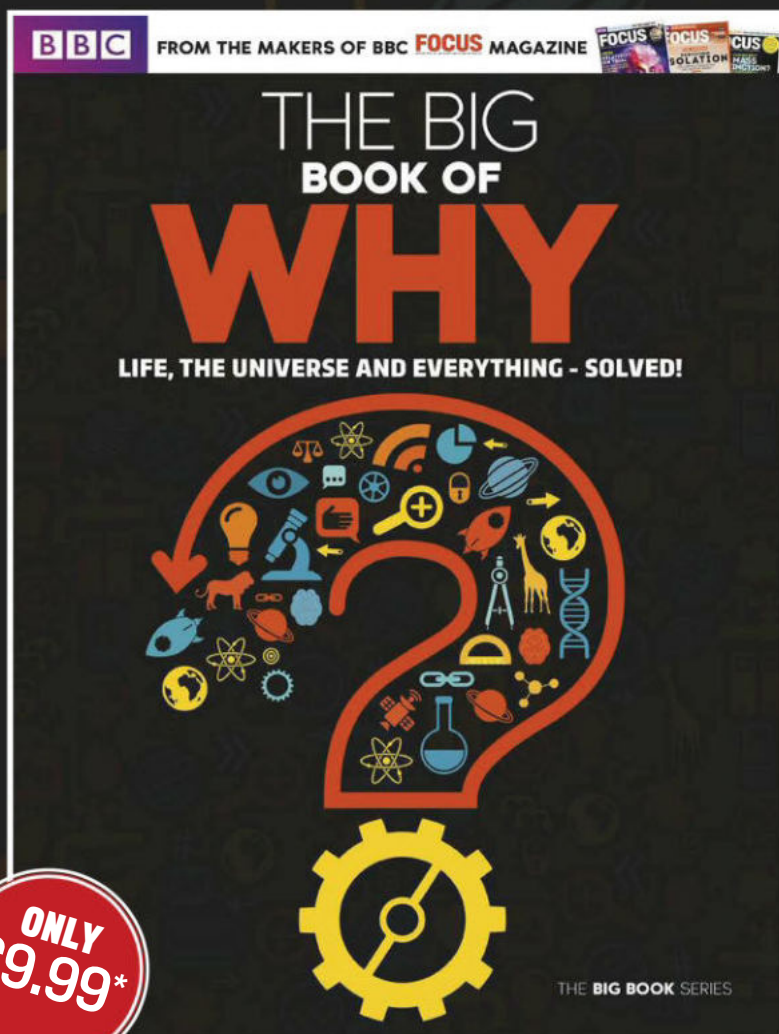
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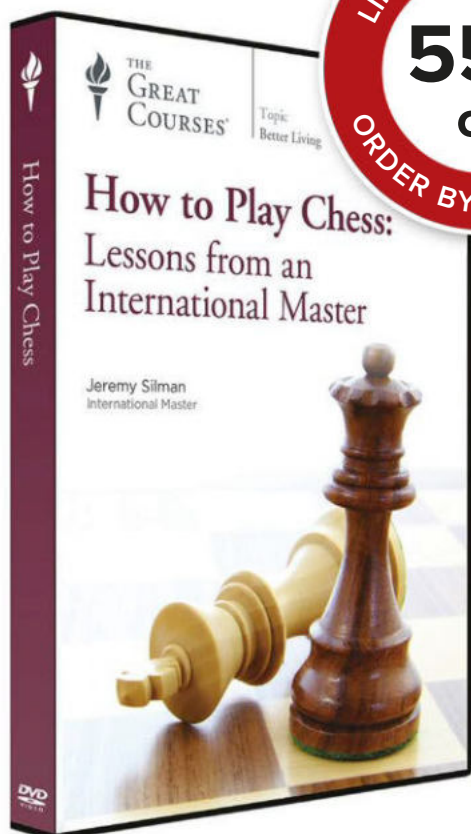
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THE FUTURE OF GADGETS

# TECH HUB

EDITED BY **RUSSELL DEEKS**

**THIS MONTH** ➔

**BILL THOMPSON**  
All hail smart  
materials  
p87

**HIGH-TECH  
HIBERNATION**  
Baby, it's cold  
outside. So why  
leave your house?  
p90

## ON THE HORIZON

### LI-FI LIGHT BULB

A new, faster way  
to transmit data

[velmenni.com](http://velmenni.com)

LI-FI – THE wireless transmission of data using light, whether infrared, visible or ultraviolet – is a technology that was first mooted by Prof Harald Haas at the University of Edinburgh around five years ago. So far no company has managed to bring a consumer Li-Fi product to market, but now it looks like a start-up called Velmenni may be the first to do so. Velmenni is based in Delhi, India and Tartu, Estonia, and its engineers recently demonstrated a ➔





Velmenni's Jugnu light bulb is capable of two-way transmission at rapid speeds

➔ light bulb called Jugnu that's capable of two-way data transmission at speeds of up to one gigabit per second (Gbps) – nearly 100 times faster than standard Wi-Fi.

Velmenni's bulb uses VLC – visible light communication. Essentially, it's like sending Morse code signals with a torch, only much, much faster: an LED flashes on and off at super-high speeds to create a series of '1s and 0s'. These pulses occur much too quickly to be registered by the naked eye, but they're easily decipherable by any device equipped with the appropriate transceiver.

Li-Fi offers several advantages over 'traditional' Wi-Fi. Increased speed is a key benefit, as mentioned above. Early in 2015, speeds of 224Gbps were demonstrated under lab conditions at Oxford University. Another is that, because it operates in the light rather than the radio portion of the electromagnetic spectrum (unlike Wi-Fi, which is a radio frequency or 'RF' technology), Li-Fi won't interfere with equipment that relies on radio communications. Therefore, it can be safely used in planes and hospitals.

On the downside, light doesn't penetrate through walls, so Li-Fi communications are strictly limited to a single room – that does, of course, mean that data transfers are much more secure. No more getting your Wi-Fi 'slurped' by the neighbours! And there's no need to leave the lights blazing. Li-Fi will still

work even with light levels reduced to such an extent that it feels like you're sitting in the dark.

Speaking to the *International Business Times*, Velmenni's CEO Deepak Solanki said: "We are doing a few pilot projects within different industries where we can utilise VLC technology. Currently, we have designed a smart lighting solution for an industrial environment where the data communication is done through light. We are also doing a pilot project with a private client where we are setting up a Li-Fi network to access the internet in their office space."

Various other companies have also been working on designing applications for Li-Fi, and Velmenni hopes to be able to license its tech to such developers.

So is this the end of the line for Wi-Fi? Given the extent to which it's become part of the fabric of all our lives and homes, probably not, at least not for a while – but do expect to see developments in the Li-Fi sector continuing apace. What's more, Wi-Fi could have a future as a means of wireless power transmission, if research at the University of Washington and the Korea Advanced Institute of Science and Technology comes to fruition. But that's a story for another day...

**RUSSELL DEEKS** is a freelance technology journalist, and Contributing Editor of *Focus*

## TECHOMETER

### WHAT'S HOT

#### GOGORO SCOOTERS

We first told you about the Gogoro electric scooter and its innovative batteries in our August issue. Now, after a successful launch in Taiwan, it's headed to Europe. Amsterdam will be the first city to get a network of Gogoro charging stations, early in 2016, followed later in the year by other, as yet unspecified, European cities.



### WHAT'S NOT

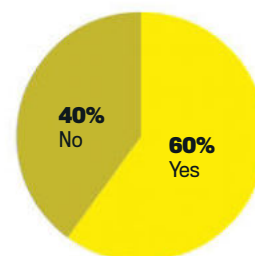
#### VTECH TOYS

VTech, which makes kiddy-friendly tablets and various 'smart' toys, has had to suspend most of its online services after a huge data breach occurred in November. Usernames and passwords were leaked in their millions. More worryingly, there's some evidence that children's photos and other personal information may also have found their way into unauthorised hands.



### READER POLL

Do recent data security breaches worry you?





## THE NEXT BIG THING

## SMART MATERIALS AND SELF-REPAIRING PAINT

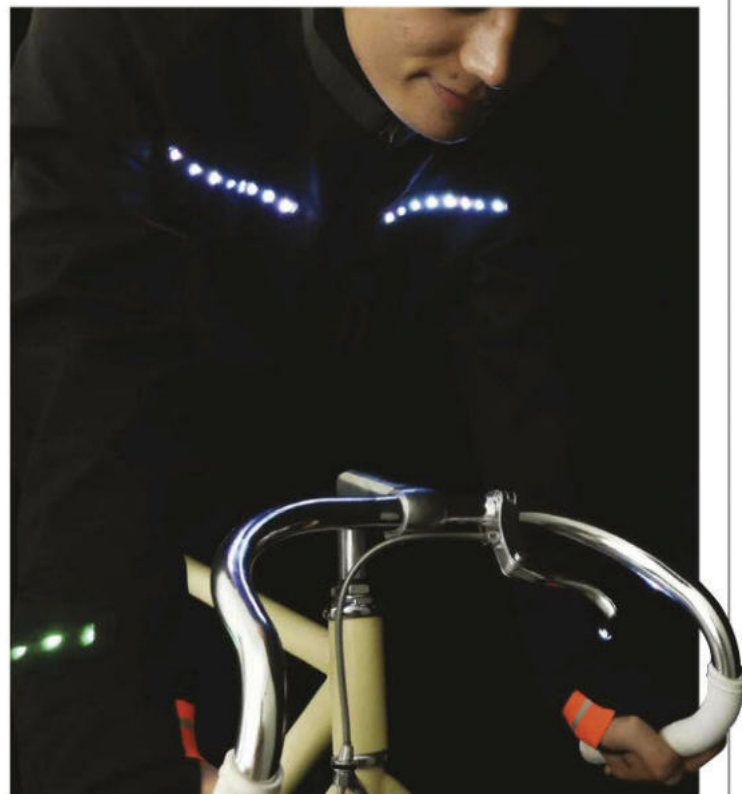
The future's so bright, Bill's gotta wear electrothermic shades

**T**HE ABILITY TO design materials with particular physical properties is one of the things we've built our world around. For thousands of years we've made our homes from brick, concrete, steel and glass, inventing new materials where we couldn't find natural ones that fitted the bill. These days, we know enough physics and chemistry to design materials with more specific properties, and the growth of nanomaterials like graphene, composite polymers and new ceramics seems unstoppable. And now we're seeing the development of 'smart materials' that adapt to their environment.

Smart products such as self-dimming, self-cleaning glass and self-healing paint are already available. Some of these materials are quite complex internally. In electrothermic glass, several stacked porous layers are printed on top of each other and sandwiched between two glass panels. Low-voltage electrical charges activate an electrochromic

layer which changes colour from clear to dark. Once you have this glass in place, you can control it in a variety of ways via a building management system. But smart materials will soon be used beyond buildings and vehicles. Researchers like Rain Ashford at Goldsmiths University of London have been exploring ways to link sensors and fabrics to build genuinely wearable computers that respond to the user's environment or emotions.

As we build smarter materials, they'll be used to develop more advanced fabrics. A good example is an LED-equipped jacket from a startup called Lumenus. This quite literally points the way forward: the jacket interfaces with Google Maps on a cyclist's phone to provide visual cues to both the rider and surrounding traffic, with turn signals and brake lights built-in. Here, the waterproof electronics are added to the jacket, but the same technology that delivers electrochromic glass could also create fabrics that glow on demand. Build in a solar panel and wireless connections, and



The Lumenus jacket works with Google Maps to keep cyclists safe

you have a self-contained node, part of the Internet of (Wearable) Things.

Clothing that acts as a portable display is one thing, but we'll eventually reach the point where the physical properties of a nanomaterial merge with computational capability, where it becomes more useful to describe the fabric your clothes are made out of as a computer in its own right rather than a piece of clever mechanical engineering. A branch of cosmology called 'digital physics' takes this to its

logical conclusion and argues that the Universe as a whole is itself a computer, and that all behaviour can be described in this way. But you don't need to go that far to accept that your if your raincoat reconfigures itself when it's about to start pouring, it could reasonably be called a computer.



**BILL THOMPSON** contributes to [news.bbc.co.uk](http://news.bbc.co.uk) and the BBC World Service

## FROM THE LAB X-RAY... MEET XBOX

## WHAT'S GOING ON?

Scientists at the Washington University School of Medicine in St Louis, Missouri have equipped an X-ray machine with sensors and software that were originally developed for the Microsoft Xbox's motion-sensing Kinect system.

## WHY DID THEY DO THAT?

Because small children are basically

rubbish at sitting still, which means that when kids need an X-ray they often end up having three or four, because they kept moving around when it was being taken. That, of course, exposes them to more radiation than is generally considered a good thing. But the Kinect's motion sensors enable a radiographer outside the room to make sure the child is sitting still before snapping an X-ray.

## WHY USE KINECT?

Because it's affordable, and because its sensors can also detect the thickness of body parts. As kids vary greatly in size, radiographers need to calibrate their X-ray machines accordingly. Until now, this has meant brandishing a pair of steel callipers and scaring little Timmy half to death – but with Kinect's sensors, all the information needed is already to hand.



Blurred X-ray images could be a thing of the past with the new Kinect system



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\* Tested under the guidance of Prof. Jason Ellis at Northumbria University's Centre for Sleep Research.

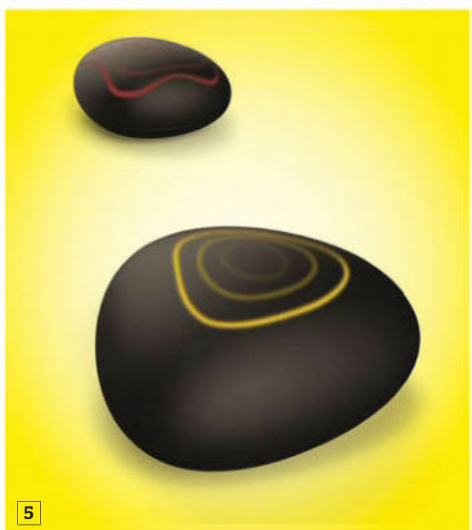
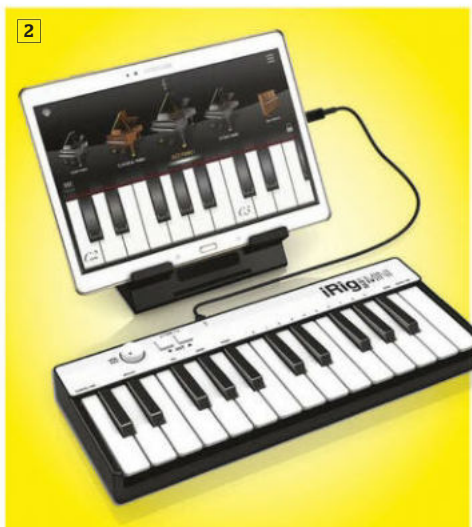
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## APPLIANCES OF SCIENCE

### 1 TOUCH SENSITIVE

Now you can turn your kitchen worktop into a musical instrument, thanks to the Touch Board Starter Kit from Bare Conductive. The kit contains a tiny circuit board computer (the Touch Board itself) and touch-sensitive 'electric paint' with which you can paint sensors onto, well, just about anything. A 'kitchen drumset' and an 'enhanced puppet show' are among the suggested projects, or you could use it to create a DIY home security system.

**Touch Board Kit**  
£95, [bareconductive.com](http://bareconductive.com)

### 2 MINI MUSIC MAKER

When it comes to making music on iOS and Android devices, IK Multimedia is the clear market leader. Its latest offering is iRig Keys MINI, a diminutive keyboard with 25 velocity-sensitive keys, octave up/down buttons and full MIDI editing capabilities. It'll work with most popular music-making apps, but iOS users get *iGrand Piano* and *Sample Tank* bundled with it, while Android users get *iGrand Piano* and *iLectric Piano*.

**iRig Keys MINI**  
£80 (£55 approx),  
[ikmultimedia.com](http://ikmultimedia.com)

### 3 GREEN WASHING

Washing machines aren't the most eco-friendly of devices, consuming large amounts of power and up to 70 litres of water a wash. Here to change that is the Drumi – a foot-powered washing machine that requires no electricity and only uses 10 litres of water (five to wash, five to rinse). Aimed at "those living off-grid or in small spaces," the Drumi can take loads up to 2kg and each wash takes just 10 minutes.

**Drumi**  
CA\$319 (£160 approx),  
[yirego.com](http://yirego.com)

### 4 STREAMING BEAUTIES

Just last month we commented on the lack of traditionally styled Bluetooth speakers... then, as if to prove us wrong, along comes the ZENSOR AX range from Dali. Combining true hi-fi sound reproduction with Bluetooth connectivity, the units are available in bookshelf (1 AX) and floorstanding (5 AX) versions and in black, white or walnut finishes. They also sport phono and optical inputs for hooking up 'legacy' sound sources.

**ZENSOR 1 AX/5 AX**  
£499/£799, [dali-uk.co.uk](http://dali-uk.co.uk)

### 5 HOME GUARD

As hype grows around the Internet of Things (IoT), so too do security concerns. But here to keep you safe from hackers, snoops and voyeurs comes Dojo, a system consisting of the pebble-shaped Dojo device itself, a cloud-based cyber security engine and an app. Together, they monitor all IoT traffic in your home and alert you if there are signs of hacking or other dubious activity.

**Dojo**  
\$99 (£65 approx),  
[dojo-labs.com](http://dojo-labs.com)

### 6 OUT OF THE BLUE

Blue light is catching up with sugar and nicotine as a health 'folk devil' of our times: it's said to reduce production of the sleep hormone melatonin, and so cause insomnia among our screen-addicted population. Apps such as *F.lux* that reduce the blue light from your PC or smartphone screen are all the rage, and now here's a box that dims the blue light from your TV. It's due to go on sale early in 2016.

**Drift TV**  
\$100 (£67 approx),  
[seesafron.com](http://seesafron.com)



# HIGH-TECH HIBERNATION

Animals have the right idea when it comes to winter – find a warm spot and sleep until spring. **Ian Evenden** wonders if we can do the same with the help of gadgets



Of course I'm feeling grizzly – there's a human inside me

## GREAT SLEEPING BEAR

This ursine sleeping bag – surely perfect for hibernation – was inspired by a bear who menaced a Bavarian village in 2006 and, erm... ended up getting shot. But that won't happen to you – mainly because you'll be too comfortable to want to venture out and trouble the townsfolk. There is one proviso, however: each 190cm fake fur slumber sack costs £1,500. Created by Netherlands-based artist Eiko Ishizawa, she wants everyone who buys one to send her photos of their adventures with the bear.

£1,500, [cargocollective.com/thegreatsleepingbear](http://cargocollective.com/thegreatsleepingbear)



## KENDAL MINT CAKE

Eaten by Sir Edmund Hillary on top of Mount Everest, this high-calorie cake is the result of a confectioner taking his eye off the pan while trying to make glacier mints. Or possibly peppermint creams. Whatever the origin, this mixture of sugar, glucose, peppermint and (frequently) chocolate is so rich in calories that a small chunk during your infrequent waking periods should be sufficient to sustain you and prevent significant weight loss.

From £1, [kendal.mintcake.co.uk](http://kendal.mintcake.co.uk)



## FITBIT SURGE

Hibernating humans don't tend to undertake much exercise, but a sports watch can still come in handy. Fitbit's Surge records your heart rate and activity levels, along with the number of calories you're burning, but more importantly will track your sleep to tell you how long you've spent in the land of nod and the quality of the snoozing you enjoyed in the process. There's a silent alarm too that gently prods your wrist to wake you in time for lunch... or spring (provided you keep its battery charged).  
£200, [fitbit.com/uk/surge](http://fitbit.com/uk/surge)



## IPAD PRO

Apple's latest grey rectangle is its biggest and most powerful yet, and can function as the sole gadget you need for your hibernation. It's your magazine rack, your games console, your TV (with a 12.9in, 2,732 x 2,048 screen equivalent to two iPad Airs) and your social media interface. You can use it to order supermarket supply drops or control other gadgets and, best of all, it's not a phone, so no one can call you.

From £679, [apple.com](http://apple.com)



## CHROMECAST

If you insist on having a TV in your bedroom, equip it with one of Google's dongles to TV any of your preferred catch-up services and all your downloaded movies. Recently updated, Chromecast offers 1080p streaming over Wi-Fi and supports many mobile apps, including the Chrome web browser. £30, [google.com/chromecast](http://google.com/chromecast)



## SMARTER COFFEE MACHINE

What could make coffee better? Wi-Fi, that's what! The hopper on top of this machine takes a full bag of beans and has a rubber seal to prevent them from going stale. Fill it up, go back to bed and when you've dragged yourself downstairs. If you're a tea drinker, then the same company makes the £100 Smarter iKettle. £180, [smarter.am](http://smarter.am)



## DYSON 360 EYE

Dyson's first robot vacuum cleaner missed its spring release date but is now on sale in Japan for an eye-watering ¥138,000 before tax (approximately £750). It runs on scaled-down tank tracks and has a 360° camera on top, with infrared sensors to prevent it from bumping into the furniture. Set its cleaning schedule, go back to sleep and let the 78,000rpm motor do its thing. ¥138,000 (£750 approx), [dyson360eye.com](http://dyson360eye.com)



## HEATED SOCKS

Should the need arise to pop outside - to leave the Christmas tree out for the binmen, for example - you can take the warmth with you by heating your socks. Powered by six AA batteries (three per leg), these socks warm your toes up to a toasty 40°C.

From £24, [springyard.se/english](http://springyard.se/english)

## OCULUS RIFT

Who needs reality? Available in 2016, and needing a reasonably beefy PC spec to power it, the Oculus Rift turns the VR helmets we were promised in the 80s from a virtual reality into... well, an actual reality - only a darn sight smaller. With one 1,080 x 1,200 OLED screen per eye, the Rift comes with an infrared sensor to track your head movements and built-in 3D headphones. Lie back and drift through virtual worlds or watch movies in a your own personal cinema without leaving your sofa. £TBC, [oculus.com](http://oculus.com)







## BRAZIL SAD LIGHTBOX

Pining for the natural light provided by the Sun as you savour your six-month power nap? Then let a little sunshine into your life with this lightbox that's designed to treat the depression that tends to strike during the dark winter months. Half an hour of this light a day can improve your mood, concentration and energy levels.

£149, [lumie.com](http://lumie.com)



## NEST THERMOSTAT

Heating control from your bed sounds like a dream come true for the truly committed hibernator, as you can keep your sleeping chamber cosy without leaving your pit. Nest even lets you can warm the boiler up for a hot bath before you've so much as poked a toe out from under the duvet. It replaces your thermostat and links to your Wi-Fi to learn your daily routine so it can automatically set the temperature at the optimum time to save energy. A smartphone app provides fine tuning.

£199, [nest.com](http://nest.com)



## PICOBREW

Many people enjoy a beer of an evening... the only problem is, acquiring it usually means leaving the house. So why not sidestep any unnecessary social interaction by brewing your own?

With self-contained packages of ingredients and controls for ABV and bitterness, PicoBrew is a Kickstarter campaign that wanted \$200,000 but got \$1.3m, so we're expecting a decent pint.

\$599 (£400 approx),

[picobrew.com](http://picobrew.com)



## ROBOT FINGERS

From South Korea come the MicroBot

Push devices that take the hard work out of pressing light switches. Controlled from a smartphone app, they connect to Wi-Fi and move in response to your inputs, to press buttons and swipe touchscreens while you lift barely a finger.

From \$39 (£26 approx),

[prota.info](http://prota.info)



## WEATHER STATION

How do you know when spring has sprung and it's time to throw back the duvet and halt your hibernation? With a wireless weather module placed outside your cave that sends updates to your smartphone, obviously. This one also comes with a second module to keep indoors that lets you know when six months of snoring has raised the amount of CO<sub>2</sub> in your cave to an unhealthy level. If the top of the indoor unit glows red when you touch it, you know it's time to open a window.

£169, [netatmo.com](http://netatmo.com)





## HUE

Philips' Wi-Fi light bulbs might look like a solution in search of a problem, but for the hibernating human they address a specific need: they let you precisely control the light levels throughout your house without leaving your bed. With one of these in every socket you can control the ambience of your entire cave with a mobile app.

From £30, [meethue.com/en-gb](http://meethue.com/en-gb)

## SAMSUNG DV8000 TUMBLE DRYER

If it's too cold to go out to the washing line or you just can't be bothered to hang the laundry up, this Samsung dryer can help.

With its oversized door, 9kg capacity and smartphone app that tells you when it's finished, Samsung has made a dryer for people with something better to do... like going back to bed.

£799, [samsung.com/uk](http://samsung.com/uk)



Long time, no see.  
So Jägerbombs  
all round?

## TELEPRESENCE ROBOT

Missing your mates? Designed to make your presence felt in the office when you're working from home, you can send this unholy amalgam of iPad and Segway out to catch up with chums while you stay indoors. It even adjusts its height if your pals prefer sitting down.

\$2,499 (£1,675 approx),  
[doublerobotics.com](http://doublerobotics.com)

## AQUAPONICS GARDEN

Green leaves are a good source of nutrition (in between bites of Kendal mint cake), so why not grow your own indoors. These water gardens have fish living below the roots to provide the occasional blob of fertiliser while the plants keep the water clean.

\$60 (£40 approx),  
[backtotheroots.com](http://backtotheroots.com)



## SLEEPPHONES

Nodding off can be difficult, especially if the bear sleeping beside you is snoring. Block out the noise and listen to the soothing sounds of the forest (or dubstep, if that's what relaxes you) by streaming music from your phone to this Bluetooth-enabled headband, which contains hidden headphones.

£30-£100, [www.sleepphones.co.uk](http://www.sleepphones.co.uk)

## RELAXWELL DELUXE FAUX FUR HEATED THROW

Feeling the winter chill in your chosen hibernation spot? This furry electric blanket is the closest you'll get to snuggling up to mama bear to benefit from a bit of extra warmth. Three hours' use costs less than a penny and once it's plugged in it heats up in five minutes - there's even a built-in timer to make sure you don't burn your house down while you're happily dreaming away in the land of nod. After all, nothing interrupts hibernation quite like a visit from the fire brigade! Its removable cover is washable and tumble dryer proof.

£99.95, [johnlewis.com](http://johnlewis.com)





# WHAT DINOSAURS LOOKED LIKE

**BY JOHN PICKRELL**

Today we take the appearance of dinosaurs for granted, but it's taken centuries of careful study to learn how to accurately read the clues in the fossil record

**B**

ACK IN OCTOBER 2015, a new dinosaur was revealed from the 66-million-year-old Hell Creek formation in South Dakota, USA. Colourful pictures of this swift, bipedal predator – covered in feathers and with a jaw full of sharp teeth – were published around the world.

Experts behind the discovery reported that *Dakotaraptor* had large, sickle-shaped claws on the second toes of its hind feet, and would have been about five metres long and slightly taller than a human. This made it one of the largest ever dromaeosaurs ('swift seizers'), the group to which *Velociraptor* also belongs. We take these kinds of reconstructions for granted these days, but just how realistic are they, and how do we know what dinosaurs really looked like?

The first attempts by humans to imagine the animals that left fossils or footprints of themselves behind were in prehistory, and there are hints that dinosaur remains made it into many ancient mythologies. Dragons appeared in Chinese texts as far back as 1100BC, and may have been influenced by dinosaur bones.

Similarly, griffins – beasts that combine an eagle with a lion – are known from Ancient Greece as early as 700BC; the inspiration may have come from fossils of the beaked dinosaur *Protoceratops*, remains of which are still found in the deserts of Central Asia today.

When ancient people were faced with strange bones, they did exactly what we do today, and used the best knowledge available to reconstruct the creatures that left them behind. Sometimes this resulted in poor



The dinosaurs in Crystal Palace Park look quite different to how we visualise the animals today

conclusions. The first name assigned in print to any dinosaur remains was the ignominious title of *Scrotum humanum* – a label given by British physician Richard Brookes to the broken end of a femur in 1763, believing it to be the fossilised testicles of a Biblical giant. We now know that the leg bone belonged to a *Megalosaurus* – correctly described as an extinct reptile by William Buckland in 1824. You can't entirely blame Brookes for his conclusions, as dinosaurs would not be described as a group until 1842. That was when Richard Owen, head of what is now the Natural History Museum, revealed to the world a new class of strange, extinct creatures he called dinosaurs, meaning 'fearfully great reptiles'.

He imagined *Iguanodon*, *Megalosaurus* and *Hylaeosaurus* to be reptiles with legs sprawled out to the sides, with scaly grey or green skin: something like modern lizards or crocodiles. In 1854 artist Benjamin Waterhouse Hawkins created life-sized sculptures of these animals as directed by Owen, and you can still see these on display in Crystal Palace Park in south London. Visit them and you will see they look very



**> IN A NUTSHELL**

Dinosaurs roamed the planet over 65 million years ago, but by studying the shape of their bones and other details of their fossils, scientists have pieced together how they would have looked in real life.



→ different to how we depict dinosaurs today.

Over time, we have come to completely revise our understanding of the appearance of dinosaurs, and much of this began with the description of another American dromaeosaur called *Deinonychus* in the 1960s. John Ostrom at Yale University made the revolutionary suggestion that this species was a bird-like, fast, warm-blooded pack hunter, and so began the 'dinosaur renaissance' of the 1960s and 70s. Ostrom championed the idea that birds were dinosaurs, and was spectacularly vindicated when *Sinosauropteryx*, the

first known feathered dinosaur, was found in China in 1996.

## FIRST STEPS

When faced with new fossils today, palaeontologists have a much bigger body of knowledge to draw upon when creating reconstructions. In fact, our knowledge has increased to the degree that – somewhat miraculously – we can tell the colours of the feathers of a range of dinosaur species.

All dinosaur reconstructions begin with their fossilised bones. If palaeontologists are lucky enough to have found a fairly complete skeleton,

they can arrange these bones into the appropriate order – based on how the bones of birds, crocodiles and even people are arranged – and start to get a sense of the shape of the creature.

Complete dinosaur skeletons are, however, very rare. The majority of fossil specimens have bones missing, and a great number of species are only known from a fraction of the original skeleton. In these cases, the bones of different specimens can be compared to fill in the gaps, and if there are parts of the skeletons that are still unaccounted for, experts will often look to related species of dinosaur for help with the reconstruction.

## THE KEY EXPERIMENT

Dinosaurs weren't just green and black. Recent research allowed scientists to unveil the true colours of one of these prehistoric animals

BACK IN 2010, *Sinosauropteryx* became the first dinosaur to be illustrated in its true colours. Since then, other feathered dinosaurs – including *Archaeopteryx* and *Microraptor* – have had their colours determined too.

This extraordinary detective story began with the discovery of fossilised melanosomes. These are

the tiny packages of pigment inside feathers and hair in living birds and mammals, and are responsible for making your hair black, brown, blond or ginger. These melanosomes are incredibly tough, and under the right conditions can survive hundreds of millions of years in fossils.

When you look at the feathers of a living bird under a high-powered electron microscope, you can see melanosomes

of different shapes. Zebra finches have round 'phaeomelanosomes' in the orange part of their feathers and sausage-shaped 'eumelanosomes' in the black parts. A team led by Mike Benton at the University of Bristol used this technique to look at the downy feathers along the head, neck and back of the fossilised *Sinosauropteryx*. They found that this carnivore was ginger with white stripes down its tail.



*Sinosauropteryx* lived around 126 million years ago in what is now northeastern China

Evidence of feathers can be seen in the fossilised remains of the carnivore



Detailed knowledge of the anatomy of a range of modern species (a field known as comparative anatomy) is helpful here, and many dinosaur experts are excellent anatomists. To those in the know, small details of the shape of bones can reveal a great deal of information about the animal they came from. For example, dinosaurs and birds (which are a kind of theropod dinosaur) are unique in having a hole in their pelvis called a 'perforated acetabulum' into which the top of the thigh bone (femur) fits on each side. This is a unique trait of dinosaurs, allowing them to stand erect with their legs underneath their bodies, rather than sprawling out to the sides as in other reptiles. The dinosaur hip also allows experts to identify between the two major branches of the dinosaur family – ornithischians and saurischians.

Theropods, the carnivorous group of saurischian dinosaurs to which *T. rex*, *Allosaurus*, and now *Dakotaraptor* belong, have a series of other telltale traits in the fossils. These include hollow bones full of air pockets, three fingers on the hands, and much reduced fourth and fifth digits on the feet. Maniraptorans, the group of theropods from which birds evolved, have more distinct features, including an unusual wrist joint with a bone called a 'semilunate carpal'. This gave these carnivores more flexible wrists – useful for seizing prey with their hands – and allowed the flight stroke of birds to evolve.

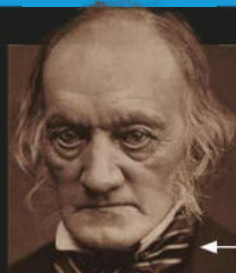
When you're out on a dig with experts you realise that even small details, such as the shape of teeth or the curves of limb bones, are enough for experts to make rapid assessments about the specific types of dinosaur that they belonged to.

## BEYOND BONES

Bones, however, are only the start of a dinosaur reconstruction. It's also important to think about muscles. For example, discs of muscle between the vertebrae of a sauropod dinosaur such as *Brachiosaurus* or *Diplodocus* would have made a great difference to the overall length of the animal. Muscles are added by referencing the exact positions and shapes of muscles in living animals. Fossilised bones often have 'muscle scars' that show attachment points, which aid in this process. Since we know

## CAST OF CHARACTERS

Six innovative scientists who helped us decipher what dinosaurs looked like



**Richard Owen** (1804–1892) was head of what is now the Natural History Museum. He was an influential anatomist and palaeontologist, who described dinosaurs as a group. He reconstructed a series of the earliest known species, including *Megalosaurus*, *Iguanodon* and *Hylaeosaurus*.



**John Ostrom** (1928–2005) discovered and described *Deinonychus*, now hailed as one of the most important fossil finds in history. He reconstructed it as a speedy, warm-blooded predator – at odds with the perception that dinosaurs were slow and lumbering. He brought back the idea that birds evolved from dinosaurs.



**Robert T Bakker** (1945–) was a student of John Ostrom. Bakker went on to lead the charge of the 'dinosaur renaissance', theorising on physiology and locomotion and stirring up controversy by suggesting that, unlike modern lizards, dinosaurs were warm-blooded. The jury is still out on that one.



**Gregory S Paul** (1954–) is an artist and palaeontologist whose books and anatomically accurate dinosaur illustrations have inspired a generation of artists and many of the dinosaur illustrations you see today. His work pioneered the revised look of dinosaurs in the 1970s.



**Mike Benton** (1956–) is a palaeontologist at the University of Bristol. He led a team of researchers in 2010 to determine the colour of dinosaurs. They showed that *Sinosauropteryx* was covered in fluffy ginger and white feathers.



**Xu Xing** (1956–) has discovered more dinosaurs than just about anyone else alive today. These include more than half of the feathered dinos found in China.





## TIMELINE

How our knowledge of dinosaurs has improved over just a couple of centuries

1842

Richard Owen names dinosaurs as a group. Early depictions show them as giant lizards.



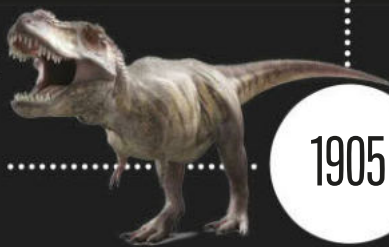
1824

*Megalosaurus* is described by William Buckland (pictured) as a giant reptile.



1964

Giant carnivore and dinosaur-poster-boy, *Tyrannosaurus rex* is named by Henry Fairfield Osborn, president of the American Museum of Natural History.



1905

*Deinonychus* is discovered by John Ostrom, leading to the 'dinosaur renaissance' – a rebirth of interest and research into the animals.



1996

The first known feathered dinosaur, *Sinosauropteryx*, is discovered in China by a team including Canadian dinosaur hunter Philip Currie.



2010

*Sinosauropteryx* becomes the first dinosaur to have its colours revealed, thanks to preserved melanosomes found in its fossilised feathers.



2014

New fossils allow scientists to piece together the detailed appearance of *Spinosaurus*, showing it was the largest ever carnivorous dinosaur. It was adapted to life in and out of water.



➔ that larger, heavier modern animals have bigger marks, we know we need to add bigger muscles to those dinosaurs.

Our understanding of the finer details of dinosaur anatomy has altered over time, and continues to improve with 3D computer models that use the physiology of living animals to make predictions about extinct species. Sauropods, like *Diplodocus*, used to be depicted with their heads held high on their necks and their tails dropping down to the ground, but we now know this wouldn't have been possible. Instead, we reconstruct them with their necks and tails in a more horizontal position, acting as counterbalances to each other. Palaeontologists are increasingly making use of digital, biomechanical models to test their ideas about how dinosaurs walked and used their jaws.

Finally, layers of fat and skin are added to our reconstructions, as well as scales, feathers, armour, crests and any other features such as cheeks, lips, claws and beaks. There are surprising pieces of evidence that come to bear on these decisions too. We have some truly incredible skin impressions for a range of dinosaurs – particularly herbivores like *Edmontosaurus* and *Saurolophus*. The prevalence of scaly skin impressions in the fossils of herbivorous dinosaurs has led experts to believe that the majority had scales instead of feathers (although a handful of herbivorous dinosaurs have been found with bristles and other feather-related features).

We also know that some herbivores, particularly the armoured ankylosaurs, were covered in defensive bony plates, spikes and knobs. These bony growths in the skin, known as osteoderms, often fossilised and give a good sense of how animals like *Scelidosaurus* – discovered in Dorset in the 1850s – would have appeared in life.

In herbivorous dinosaurs there are other features that we can infer from the bones in the skull. Duck-billed hadrosaurs have large grinding teeth at the backs of their jaws, and it's likely that these were covered with cheeks, allowing them to hold more food in their mouths for chewing before swallowing. In other dinosaurs, such as *Protoceratops*, *Triceratops* and *Oviraptor*, we can see the inner bony part of a beak that, in life, would likely have been covered with an outer keratinous layer as in birds today.



## NEED TO KNOW

A quick glossary of key terms used in dinosaur appearance

### 1 COMPARATIVE ANATOMY

The study of similarities and differences in the physical features of various species. This allows experts to make informed guesses about the appearance of extinct species based on living animals.

### 2 MELANOSOMES

These tiny granules of pigment are responsible for the colouring of hair and feathers in animals and birds. Preserved melanosomes in a *Sinosauropteryx* fossil revealed this dinosaur's true colours.

### 3 PALAEOLOGY

The study of prehistoric life, based on the fossils of animals, plants and other organisms, as well as the ages and details of the layers of rock they were found in.

### 4 THEROPOD

This large group of bipedal and mostly carnivorous dinosaurs includes *T. rex*, *Allosaurus* and *Sinosauropteryx*. The first birds evolved from theropods around 150 million years ago.

Keratin is the same tough protein that feathers, hair, fur and fingernails are made of. Did dinosaurs have lips? This is something we still don't know, and is an area of current debate.

## FLUFFY THEROPODS

Carnivorous theropods, in contrast to the herbivores, were frequently covered in feathers. The incredible fossils of nearly 50 species – mostly from China's northeastern province of Liaoning – show a range of feathery coverings, from downy, insulating 'dino-fuzz' to flashy display and flight feathers. Some of these animals are so exquisitely preserved that we can see the shape and arrangement of feathers right across their bodies.

Though most of these feathered dinosaurs have been found in China, the spread of species across the family tree suggests that most theropods in other parts of the world were feathered too – we just have a fantastic



*Zhenyuanlong* was discovered in the Liaoning region of China. It lived in the Cretaceous period, around 125 million years ago. The fossilised remains suggest that this dinosaur was covered in feathers

window into the past with Liaoning because of the type of preservation found in its volcanic deposits.

Sometimes we have other evidence of feathers, such as marks on the forearm bones of *Velociraptor* which correlate to the 'quill knobs' where the ligaments of flight feathers attach on pigeons today. It's this feature in *Velociraptor* fossils from Mongolia that led experts to assume all dromaeosaurs had small 'wings' on their forearms – a feature now confirmed by the Chinese fossil of another new dromaeosaur called *Zhenyuanlong*, described in 2015 by scientists including Dr Stephen Brusatte at the University of Edinburgh. Quill knobs were also found in the *Dakotaraptor* fossil, and the scientists behind this discovery, led by Robert DePalma at the Palm Beach Museum of Natural History in Florida, estimated it to have had a wingspan of around a metre.

Artists also play an essential role in bringing dinosaurs to life, and often have expert anatomical and palaeontological knowledge to build on the scientific evidence with informed guesswork. Without these palaeoillustrators, such as Emily Willoughby who created the lovely feathery image of *Dakotaraptor*, the appearance of these animals would live only inside the minds of the scientists who discovered them.

In the last five years, the colours of dinosaur feathers have come into focus, but we may soon have a good idea of dinosaur skin colours too. We

already know from the patterns of scales on some 'mummified' fossils that *Edmontosaurus* was probably adorned with stripy patterns, even if we're not sure what colour they were, and a number of studies have started to use electron microscopes to look at the structural patterns of tiny packages of pigment in the skin. Last year, an international team of scientists used this technique to show that a prehistoric marine reptile called a mosasaur had a dark back and a pale-coloured belly, while another marine reptile – a dolphin-shaped ichthyosaur – had universally dark pigmentation. It won't be long before similar methods are used to determine the colours of dinosaurs too.

Reconstructing animals from fossils is partly guesswork, but it's informed guesswork, building on the knowledge built up over the centuries by pioneering palaeontologists. Today, we have a better idea of the appearance of dinosaurs than ever before. ■

JOHN PICKRELL is a science journalist and author of *Flying Dinosaurs: How Fearsome Reptiles Became Birds*

## DISCOVER MORE!

BBC  
RADIO

4

To listen to an episode of *Natural Histories* about dinosaurs, visit [bbc.in/10vt8qN](http://bbc.in/10vt8qN)



## Don't miss our new-look February issue!

We've taken *BBC Focus* into the lab and distilled its essence to create something new, but familiar. Our aim: to make *Focus* the ultimate magazine for curious minds.

First off, we want to give you **more of what you love**. Our Q&A section will be **bigger and bolder** than ever, we'll have even **more spectacular photography**, and each issue will be stuffed with **the latest scientific discoveries** from around the world.

We're **obsessed with what the future will look like**, so instead of simply reviewing today's technology, we'll now focus on the **technological innovations that will shape tomorrow**.

Finally, as you might have noticed from this page, the new look will be **cleaner, smarter and easier to read**. There's tonnes more to talk about, but we'll let you discover it all for yourselves in our next issue. See you then...

PHOTO: ESO, GETTY, BBC, ISTOCK



**NEW LOOK  
FEBRUARY  
ISSUE  
ON SALE  
4 FEB**

### SPACE

## The hunt for alien life

Stephen Hawking and Astronomer Royal Sir Martin Rees are launching a search for alien life this year. We investigate what will happen if they succeed.

### NATURE

## HOW ANIMALS PREDICT EARTHQUAKES

Animals often flee the site of a natural disaster hours in advance. So how do they sense impending danger – and how can we harness this ability?



### TECH

## VIRTUAL REALITY IS FINALLY HERE

Find out how designers, engineers and scientists are using the virtual world to help them shape the real one.



### COLUMNIST

## ROBIN INCE

Meet our newest contributor Robin Ince, comedian and co-presenter of Radio 4's *Infinite Monkey Cage* with Prof Brian Cox. He'll be getting to grips with some of the biggest ideas in science.





# TO DO LIST

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## PICK OF THE MONTH



➔ SINCE *STARGAZING LIVE* first appeared on our screens in 2011, space has been getting us more excited than ever. In the last five years, humans have landed a car-sized rover on Mars, flown a spacecraft past Pluto and touched down on a distant comet. Now, as this issue goes to press, we're about to send the first British astronaut to the International Space Station. Not even George Lucas could have made up all of that.

Major Tim Peake's mission to the ISS will provide the main focus for this sixth series of *Stargazing Live*. Time and technology allowing, presenters Professor Brian Cox and Dara Ó Briain will link up with Tim to find out how he's adapting to life in space. We'll discover how Tim and the crew cope with the daily routine on the ISS, how space affects Tim's body and what experiments he'll carry out on board. Meanwhile, Liz Bonnin will report live from Tim's earthly base – the European Space Agency's astronaut training centre in Cologne – where a very special guest will be venturing inside a centrifuge. Sick bags at the ready!

But it's not all about Major Tim. There'll also be updates from the New Horizons, Cassini and

Rosetta missions, as well as spectacular images from the Hubble Space Telescope to celebrate its 25 years in orbit. Other topics up for discussion this time around include rogue planets, gravitational waves and space colonisation.

In keeping with tradition, viewers will also get the chance to make a discovery of their own. In previous series we've had supernovae, gravitational lenses and exoplanets but this time around the goal is to find a pulsar – a rotating neutron star that beams electromagnetic radiation into space. Dame Jocelyn Bell Burnell will be on hand to explain how she discovered the first pulsar in 1967.

Finally, Professor Lucie Green will offer tips to those who'll be braving the wintry nights and looking skywards this January. Look out in particular for the ISS – if you squint, you might just be able to see Tim Peake at the window.

**JAMES LLOYD**



Tune in to *Stargazing Live* on BBC Two on the 12-14 January to stay up-to-date with space news

## DON'T MISS!



### How The Universe Works

Lift the bonnet of the cosmos and find out what keeps it running. **p103**



### Robot

Visit Newcastle to get up close and personal with your favourite bots, cyborgs and droids from the past 60 years of film and TV. **p105**



### The Confidence Game

Maria Konnikova brings psychology theories to bear on real-life tales of cons and scams. **p106**



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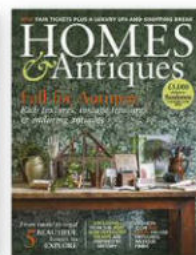
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# WATCH

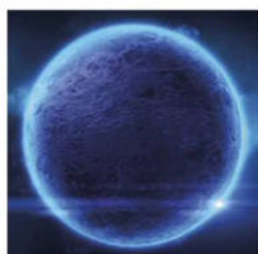
TV & ONLINE

WITH JAMES LLOYD

JANUARY

## How The Universe Works

Discovery, Sundays, 8pm



Find out how the Universe formed

WHAT IS THE Universe made of? How did life begin? Why doesn't the Moon fall down? Where does time go? Humans have been asking questions about the cosmos ever since we first found ourselves on a fragile rock beneath a great ball of light in the sky. This series provides some of the answers.

25 JANUARY

## Explorer: Call Of The Wild

National Geographic, 8pm



Get back to nature this January

EVER FELT THE urge to leave your chair, throw the computer out of the window and go and live in the woods? You're not alone. This one-off programme explores how people are disconnecting from technology and reconnecting with nature. Forest bathing? Phone addiction therapy? Hunting our own dinner? Sign us up!

30 JANUARY

## Nature's Boldest Thieves

Yesterday, 6pm



Yeah, but is it gluten free?

AS ANYONE WHO'S had a sandwich snatched from their hand by a hungry seagull will know, animals can be crafty thieves. From foxes and squirrels to gulls and peanut-butter-loving badgers, Lucy Cooke reveals how urban animals are learning to steal food from us humans. Oi! Come back here with that pasty!

JAMES LLOYD is Editorial Assistant at *BBC Focus Magazine*

**EDITOR'S CHOICE**



Feast your eyes on the best from the BBC

AVAILABLE NOW

## BBC Store

LAUNCHED IN NOVEMBER 2015, BBC Store is the new one-stop shop for buying and downloading programmes from the Beeb's glorious archive. There are highlights from 60 years of television, including comedy, drama and music, as well as plenty of science-themed delights to feast your eyes and ears on.

A good place to start is the BBC's flagship science series *Horizon*, which recently celebrated its 50th birthday. BBC Store is currently hosting episodes going back to 2008, shedding light on topics including the dark web, Ebola, gravitational waves, binge drinking, and health tests.

If jaw-dropping vistas and beautiful beasts are more your thing, there are plenty of David Attenborough series

to get stuck into. From his latest show *The Hunt* to blue-chip classics such as *Planet Earth* and *The Blue Planet*, there's enough to keep nature lovers entertained for days. We're also big fans of George McGavin's *Monkey Planet* – an endearing, emotional look at the lives of our cousins – and *Bill Bailey's Jungle Hero*, in which the comedian tells the story of Alfred Russel Wallace – Victorian explorer and co-discoverer of natural selection.

Other highlights on BBC Store include *Catching History's Criminals: The Forensics Story*, *The Science Of Doctor Who* and *Focus* regular Helen Czerski's latest series *Colour: The Spectrum Of Science*. Check out the full selection at [store.bbc.com/factual/science](http://store.bbc.com/factual/science)

PHOTO: DISCOVERY NETWORKS, BBC, ISTOCK, NATIONAL GEOGRAPHIC CHANNEL





# LISTEN

## BBC RADIO PROGRAMMES

WITH JAMES LLOYD

FROM 6 JANUARY

## Science Stories

BBC Radio 4, 9pm



CORNELIUS DREBBEL SOUNDS like a character from a children's book. Born in 1572, this Dutchman built the first submarine, dabbled in alchemy and surprised the court of King James I by turning summer into winter. Kicking off this new series of *Science Stories*, Philip Ball asks if Drebbel was also the first person to create oxygen.

FROM 12 JANUARY

## The Truth About... Diabetes

BBC World Service, time TBC

THERE ARE AROUND 350 million people worldwide living with diabetes – a major cause of premature illness and death. This four-part series explores the global epidemic, reporting from Sri Lanka, Mexico, Tonga

and the United States on how diabetes is affecting communities, and what's being done to improve the situation.

FROM 18 JANUARY

## Discovery: Scottish Dolphins

BBC World Service, time TBC  
THINK DOLPHINS, AND you probably don't think Scotland. But the northeast of the country is home to the world's most northerly group of bottlenose dolphins. Euan McIlwraith meets the conservationists who identify and track them, and uses a hydrophone to listen to their underwater babblings. What's dolphin-speak for 'Och aye the noo'?

FROM 18 JANUARY

## The Infinite Monkey Cage

BBC Radio 4, 4.30pm

SCIENTISTS AND CURATORS take us into the vaults of the Natural History Museum, introducing their personal heroes. The early pioneers of biology, palaeontology and botany were prolific collectors, going in search of bones, animals, plants, and pretty much anything they could get their hands on.

ONLINE

## The Beauty of Equations

[bbc.co.uk/programmes/b06r50wh](http://bbc.co.uk/programmes/b06r50wh)



IF, LIKE US, you spent hours of your life staring at a chalky blackboard in school, you might be forgiven for thinking that mathematics is far from beautiful. But, as Jim Al-Khalili reveals, equations can be as emotionally fulfilling as the finest works of art.



PHOTO: GETTY



# TOUCH

## SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

## Architecture Of Radio

iOS 9.0 or later, iPhone/iPad/iPod Touch, Android version coming in 2016, Richard Vijgen, £2.29



WE'RE USED TO living in a hyperconnected world, but it might come as a shock to see all the wireless signals that surround us. *Architecture Of Radio* creates a 360-degree visualisation of these signals through sound and images, allowing you to 'see' the invisible communications networks that hold modern society together. Using your GPS location, as well as data from almost seven million mobile phone towers, 19 million Wi-Fi routers and the hundreds of satellites orbiting Earth, it's an astonishing and thought-provoking sight.

## This Is My Food - Nutrition For Kids

iOS 8.0 or later, iPhone/iPad/iPod Touch, urbn pockets, £2.29

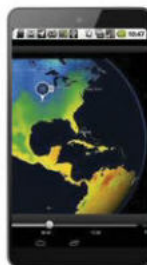


PARENTS KNOW THE benefit of a healthy diet, but getting the message across to a five-year-old who doesn't want to eat their vegetables can be like growing tomatoes in the dark. *This Is My Food* takes on that job with a cute, interactive guide that talks about all the things you might

find on your plate and why they're important to eat. With recipes and instructions for growing your own herb garden, this app turns eating a balanced diet into a game that even the most truculent toddler should be able to get behind.

## MeteoEarth

iOS 8.0 or later, iPhone/iPad/iPod Touch, Android 4.0.3 or later, MeteoGroup, free



EVER FANCIED YOURSELF as the next Michael Fish? *MeteoEarth* overlays various weather data on a beautifully rendered 3D globe. Just tap the icons to visualise information such as temperature, rain fronts, winds and cloud cover. It takes a few seconds for the details to load, after which you can swipe to rotate and pinch to zoom for a better look. The app is based on the same technology that TV weather forecasters use – although judging by the inaccuracy of some weather reports, we're not sure if that's a plus or a minus!

KATE RUSSELL is a technology journalist and *Click* presenter





# VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

FROM 22 JANUARY

## Otherworlds: Visions Of Our Solar System

Natural History Museum, London, £11, [nhm.ac.uk](http://nhm.ac.uk)

THIS EXHIBITION FUSES raw data from NASA and ESA into more than 70 stunning images, exploring the beauty of our Solar System.

23 JANUARY



## Robot: A Collection Of Robot Models, Cyborgs And Androids From TV And Film

Life Science Centre, Newcastle, [life.org.uk](http://life.org.uk)

CHECK OUT MODELS of robots, cyborgs and androids from the past 60 years of TV and film. Entry included with admission. Runs until 17 April.

2 FEBRUARY

## Bright Club

The Stand Comedy Club, Newcastle, 8:30pm-10:30pm, £4, [life.org.uk](http://life.org.uk)

LAUGH AND LEARN at this great event. Fusing science, comedy and music, this is a night out unlike any other.

6 FEBRUARY



## V For Vendetta

Royal Museums Greenwich, 6pm-8:45pm, £8, [rmg.co.uk](http://rmg.co.uk)

GRAB A SEAT at this cult film screening. In an alternative Orwellian London, a masked figure stands up to a fascist regime hell-bent on quashing freedom.

9 FEBRUARY

## Weighing Black Holes

Royal Astronomical Society, London, 1pm-2pm, 6pm-7pm (booking required for evening event), [ras.org.uk](http://ras.org.uk)

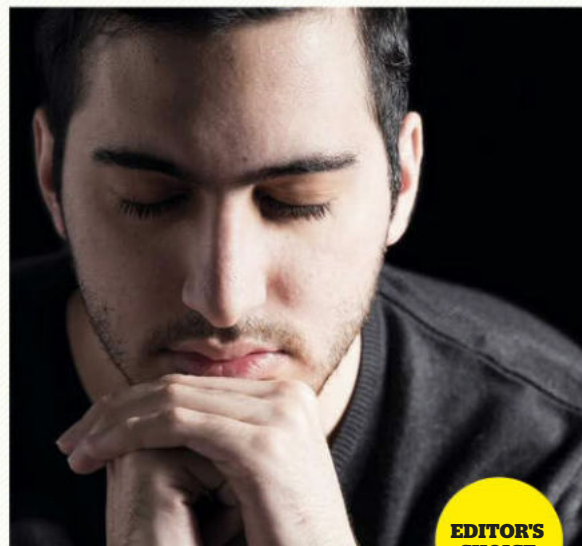
BLACK HOLES BAFFLE even the brightest minds. At this free talk, find out about their importance for galaxy formation.

14 FEBRUARY

## A Valentine's Evening With The Stars

Royal Museums Greenwich, 5:25pm-7:25pm & 6:45pm-8:45pm, £30, [rmg.co.uk](http://rmg.co.uk)

DON'T FANCY A table for two this Valentine's Day? Why not ditch the dinner date and enjoy the night sky at a planetarium show, while sipping on a glass of bubbly.



**EDITOR'S CHOICE**

5 FEBRUARY

## Friday Late Spectacular: Feeling Emotional

Wellcome Collection, London, 7pm-11pm, free, [wellcomecollection.org](http://wellcomecollection.org)



SUFFERING FROM THE post-Christmas winter blues? You're not alone. Discover the science behind human emotions, from feeling down in the dumps to over the moon. Find out about the language, behaviours and technologies we've developed to make sense of ourselves. Have a go at laughter therapy, watch a robot mimic human emotional development, experience live performances and design your own emoji.

15-19 FEBRUARY

## Destination Space

Thinktank, Birmingham, 1pm-1:30pm, [destinationspace.uk](http://destinationspace.uk)

BRITISH ASTRONAUT TIM Peake is now on the International Space Station. But what's life like in space? Find out at this show.

24 FEBRUARY

## Energy For All

Royal Geographical Society, London, 6:30pm-8pm, £10, [21stcenturychallenges.org](http://21stcenturychallenges.org)

THIS TALK DISCUSSES how we can ensure reliable, affordable and sustainable energy for the 21st Century.

29 FEBRUARY

## Body Of Essays

Wellcome Collection, London, 6:30pm-8:30pm, free, book from 29 January, [wellcomecollection.org](http://wellcomecollection.org)

FROM A CRIME author to a poet, five writers read their own 15-minute essays about a different organ of the body, as part of BBC Radio 3's series *The Essay*.





# READ

THE LATEST SCIENCE BOOKS REVIEWED

**H** Hardback **P** Paperback

## Dark Matter And The Dinosaurs

The Astounding Interconnectedness Of The Universe

Lisa Randall

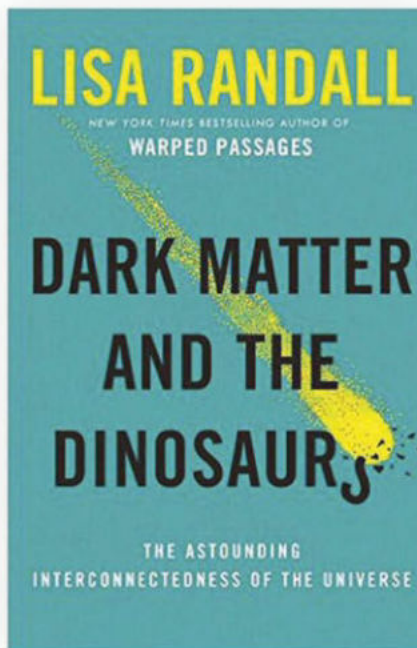
Bodley Head **H** £25.00

AT FIRST SIGHT, *Dark Matter And The Dinosaurs* looks like a title thought up by the marketing department. "Hmm, what interests the public? Dark matter is trendy. And who doesn't love a dinosaur, right?" To be fair, physicist Lisa Randall does make a tenuous connection between a new dark matter theory and the comet that is thought to have caused the extinction of the dinosaurs, but that is by no means the most interesting aspect of this book.

Much of the content takes us on a solid, if surprise-free, tour of the history of the Universe, zooming in to see how the Solar System reached its present form, and exploring the nature of comets, meteors and asteroids. But where Randall really triumphs is with her coverage of extraterrestrial impacts on the Earth. The detective story that led to the identification of the Chicxulub crater as the site of the dinosaur-killing meteoroid strike is extremely engaging.

Better still, the chapters on dark matter go far beyond most other popular books on the subject. Randall paints a truly fascinating picture of the possibility that dark matter is as rich and varied as normal matter, perhaps forming dark matter suns that pour

**"Randall paints a fascinating picture of the possibility that dark matter is as rich and varied as normal matter"**



out dark light, or are even orbited by dark planets hosting dark life.

Where the book could do better is in hitting the right level of detail. Randall dismisses modified Newtonian dynamics (MOND) – the alternative to dark matter based on a tweak to Newton's laws – with an example of a star cluster unsupported by the modified theory. Yet she continues to support dark matter, despite listing four or five examples where it fails to match observation, and it's never made entirely clear why dark matter is given the benefit of the doubt but MOND isn't. Elsewhere, it seems as if the book hasn't been adequately edited – it isn't unusual for Randall to take a page to say something that only required a couple of lines.

The climax of *Dark Matter And The Dinosaurs* is the discovery that a possible regular cycle of comet strikes – for which the evidence, it should be pointed out, is rather thin – combined with an unsubstantiated dark matter theory just *might* explain the extinction of the dinosaurs. But to consider this the highlight misses the point. This book is not about the destination, but the journey. And that is often delightful.



**BRIAN CLEGG** is a science writer whose most recent book is *Ten Billion Tomorrows*

### MEET THE AUTHOR



**Lisa Randall**

Could you explain the 'double-disc dark matter' theory that you propose in your book?

Most dark matter in our Galaxy surrounds us in an approximately spherical halo. But why is dark matter in a spherical halo, and ordinary matter in a disc – the plane of the Milky Way? This is because ordinary matter can radiate photons and cool down, which allows it to collapse into a disc. We suggest that dark matter can also radiate – not ordinary photons, but a new kind of 'dark light'. This would mean that it too could collapse into a dense disc, embedded inside the Milky Way's disc of ordinary matter.

How could we detect such a disc?

We could look for its gravitational influence. Stars go up and down through the plane of the Milky Way, and the speed with which they do so responds to gravity. So if there's a dark disc, you'd expect to see a spatial variation in the speed. Right now, the Gaia satellite is measuring the position and velocity of a billion stars in our Galaxy, and that information will help us pin down whether or not this disc exists.

So how might this disc be linked to the dinosaurs?

If you look at the dataset for large impact craters on the surface of the Earth, you find that there's marginal evidence for a periodicity, where every 30–35 million years the rate of impacts increases. We realised that this could be caused by the Solar System passing through the dark matter disc. This would give icy objects in the distant Oort cloud a gravitational kick, potentially sending them into the inner Solar System as long-period comets. We suggest that this is what happened 66 million years ago, when a huge impact wiped out the dinosaurs.





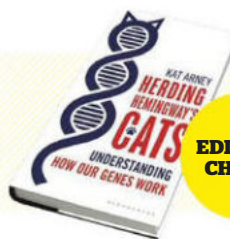
## We Are All Stardust

Stefan Klein

Scribe **P** £9.99

NEWSPAPERS ARE OBSESSED with celebrities from the arts: even Z-list actors get asked for their views on global issues if they've got a new movie out. In contrast, there's a belief that scientists must be incomprehensible and boring. The trouble is that while any airhead can interview a movie star, it takes some effort to come up with interesting questions for Nobel Prize winners. That's what gives Stefan Klein an edge in this collection of interviews with leading scientists in fields ranging from cosmology to consciousness, genomics to psychology – before becoming a writer, Klein was a scientist himself. His interviewees include some of the usual suspects like Astronomer Royal Lord Rees, but also less familiar names like neuroscientist Vittorio Gallese, discoverer of 'mirror neurones' that play a key role in social interactions. Whatever the subject, Klein elicits both neat explanations and entertaining stories and insights. So if you want to get a glimpse of the workings of some great minds – and find out how a trip in a sports car led to a Nobel Prize and what Lord Rees nearly ended up doing for a living – this is the book for you.

**ROBERT MATTHEWS** is Visiting Professor in Science at Aston University



## Herding Hemingway's Cats

Understanding How Our Genes Work

Kat Arney

Bloomsbury Sigma **H** £16.99

ERNEST HEMINGWAY'S CAT famously had six toes, as do some humans. In Kat Arney's delightful new book she explains how this condition is not the result of a mutation or error in some gene, but rather an example of how a perfectly good gene has been misregulated.

Gene regulation might seem a dry topic, but it explains how, for example, we can be 98–99 per cent identical to chimpanzees in our genes while being so utterly different in every other respect. Our genomes are packed with regulatory mechanisms with strange names such as 'fused genes', 'epigenetics', and 'RNA editing'. These enable our bodies to use our genes in a dazzling variety of ways. A similar bounty of such mechanisms in other organisms can produce stunning floral colours or rewire the brains of a fruit fly (and probably us!), leading Arney to say: "It's not what you've got, but what you do with it that counts".

Arney's book is accessible to those without a scientific background and its breezy anecdotal style makes for entertaining reading, making it a nice treat for GCSE or A-level students.

**PROF MARK PAGEL** is an evolutionary biologist and a Fellow of the Royal Society



## The Confidence Game

The Psychology Of The Con And Why We Fall For It Every Time

Maria Konnikova

Canongate **P** £14.99

THIS BOOK IS filled with real-life tales of people duped out of their life savings, tricked into bogus marriages and much more. Maybe you've been conned, but don't realise it yet, or don't want to admit it. That's what Maria Konnikova makes you wonder through her masterful blend of storytelling and psychological theory. Thanks to psychological phenomena such as 'optimism bias' and the 'better-than-average effect', we're all overconfident about our expertise, our ability to judge others' trustworthiness and the likelihood that we'll ever be the target of a con. Once we're lured in by a persuasive story our emotions take over, blinding us to what's really going on. Even as our losses mount up and the con takes hold, we keep going thanks to effects like the 'gambler's fallacy' (surely a win is due after so many losses) and the 'sunk cost effect' (our reluctance to give up on an enterprise that we've invested in).

Ultimately, what makes us vulnerable to the con is our universal need to believe that we can become healthier, happier, richer versions of ourselves.

**CHRISTIAN JARRETT** is the author of *The Rough Guide To Psychology*



## In A Different Key

The Story Of Autism

John Donovan and Caren Zucker

Allen Lane **H** £20

IN 1943, DONALD Triplett was the first child to be diagnosed with autism. Today, around 700,000 people have autism in the UK alone. *In A Different Key* tells the story of those intervening 73 years, covering the history of the disorder in a detailed, rational way.

Unfortunately, though, it's somewhat disadvantaged, being released so soon after Steve Silberman's award-winning book *NeuroTribes*, which essentially does the same thing. The timing is a shame, because *In A Different Key* is a very good book. A lot of time and effort has clearly gone into it, and the writing flows well without ever getting bogged down in needless detail. Authors John Donovan and

Caren Zucker manage to remain objective but compassionate throughout, and prominent individuals in the field are described with respect and dignity, though there are times when you feel this is very generous on their part.

It's not so much a science book as a history book with a compelling narrative, the only thing that may deter the casual reader is its 672-page length. But autism has a long and varied history, and you obviously need a big book to fit all that in.

**DEAN BURNETT** is a neuroscientist. His first book, *The Idiot Brain*, is out in February



# SCIENCE FESTIVAL GUIDE

Your pick of the best science festivals across the UK happening in 2016



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## PINT OF SCIENCE FESTIVAL 23-25 MAY 2016

Pint of Science Festival (23-25th May) brings real scientists and new research to your favourite local pub. Over drinks and a bite to eat you can pick the brains of some of the UK's most brilliant academics away from the laboratory or lecture theatre. This year's festival takes place in 20 cities across the UK, offering over 750 of the UK's best scientists for less than the cost of an average pint. Details of all our events and how to buy tickets can be found on our website.

**[contact@pintofscience.com](mailto:contact@pintofscience.com)**  
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## OXFORDSHIRE SCIENCE FESTIVAL 23 JUNE 2016 – 3 JULY 2016

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**[royalsociety.org/summer-science](http://royalsociety.org/summer-science)**  
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The **Super Precision Gyroscope** has been designed and built to the highest precision from the very start, made from solid brass with a light-weight aluminium frame. Carefully chosen stainless-steel miniature ball bearings allow it to run smoothly and almost silently. The gyroscope operates at over **12,000 rpm** using the provided **electric motor** and battery pack. The gyroscope comes with a number of attachments allowing numerous configurations to perform scientific, educational or simply mesmerising experiments. The brass disk is machined to **microns precision**, ensuring the disk is incredibly symmetrical and well balanced. The disk is then **computer balanced** to an impressive 250th of a gram accuracy! Thus giving the gyroscope a highly balanced, super smooth feel, longer spin and even quieter operation. Visit [www.gyroscope.com](http://www.gyroscope.com) for details and to see our other products.



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This beautifully made small sports car AS4 is a homage to the first Mercedes vehicle. It is powered by a Stirling Engine with its fuel source being a small alcohol burner. Made of 100 parts. Ready to run.



These miniature 3cc V-Twin combustion engines run off butane or propane gas. They are small enough to run on your desk and have an awesome v-twin sound. Just turn the valve and flick the flywheel to get it started.



This Vulcan stove fan is driven using Stirling engine technology using just the heat from a stove. It requires no external power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.



Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet a fixed distance away.



This is a Hero Steam turbine. Syringe in some water. Fill the burner with methylated spirits and light it. Moments later you have a steam turbine running. Two tiny jets of steam coming out of the side of the brass ball spins it up to 2500rpm.



These are highly polished solid metal flip over tops. They have a chrome like finish and are excellently machined. Simply spin it as normal and watch it suddenly flip over and then continue to spin upside-down.



Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you can create are mesmerizing.

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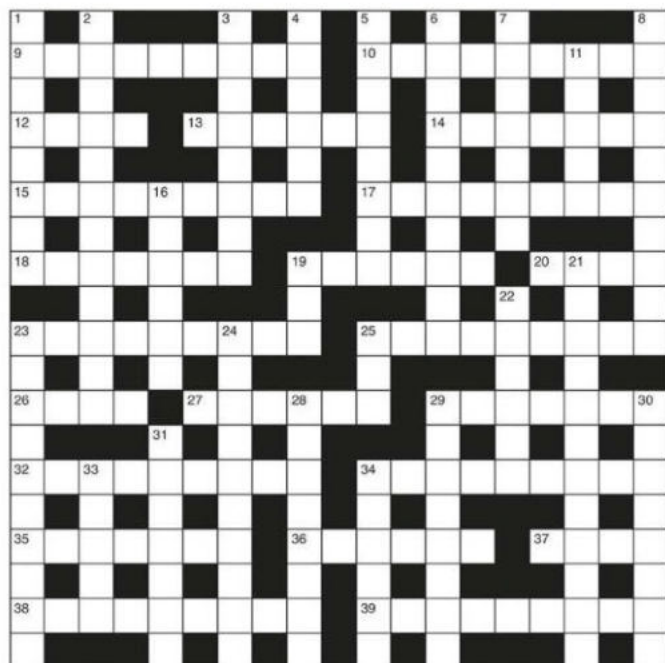
 **#WDYTA?LIVE**

 **WHO DO YOU THINK YOU ARE? LIVE**



# FOCUS CROSSWORD No 186

**More online** Solve puzzles from BBC *Only Connect* hosted by Victoria Coren Mitchell at [bbc.in/1vC0zuY](http://bbc.in/1vC0zuY)



## ACROSS

- 9 Entice rep to work nearest to an earthquake (9)
- 10 Rascal goes east to join routine opposition (9)
- 12 Cheer endlessly with point of existence (4)
- 13 Embryonic membrane gets crooked man on some charge (6)
- 14 Mute ape has accident and he's seriously injured (7)
- 15 Self-obsessed person scars us in error (9)
- 17 Most dissolve in salt water and sulphur (9)
- 18 Managed to get caught by our bitterness (7)
- 19 Larger bill includes rodent (6)
- 20 Old friend gets a stone (4)
- 23 Vapour is somehow getting round like a woodpecker (9)
- 25 Some characters of numeric shape (9)
- 26 European staff (4)
- 27 Bits of rock added to Dutch cement mixture (6)
- 29 European swine spilt ale on the ground (7)
- 32 Traded tin sculpture for plant (9)
- 34 Engineers first book for manufacture again (9)
- 35 Count is moved by force (7)
- 36 Frenchman follows a plan, setting incendiary (6)
- 37 Obscurity surrounds river amphibian (4)
- 38 Shout about trade improving, but it slows you down (9)
- 39 Rector, at home, can repeatedly be a film star (3,3,3)

## DOWN

- 1 About to get caught on ship armchair (8)
- 2 Other one has a large distinction (12)
- 3 Spray article given to skinflint (8)
- 4 Brainbox type going round island (6)
- 5 A crab wanders around tavern to find a rock (8)
- 6 A quiet pair into upsetting ghost (10)
- 7 Fat woman in a role (7)
- 8 Eel crumble recipe kept in part of brain (10)
- 11 Explosive new riot broke out (5)
- 16 Goon is eccentric, but has the same angles (6)
- 19 Talk of chlorine, say (3)
- 21 Claim to speak for bunch of academics (12)
- 22 Reversing is main dilemma of a monkey (6)
- 23 Stairs paid off for house plant (10)
- 24 Old accident suffered by student from the west (10)
- 25 Payment method for fish (3)
- 28 One route involved short-term security (8)
- 29 Encourage growth of aubergine (8)
- 30 Yes, only worried about key biological process (8)
- 31 Worry about party being a bore (7)
- 33 Understood to be in Latin (5)
- 34 Account of shot (6)

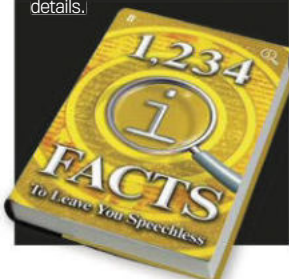
## SOLUTION TO CROSSWORD No 183

John Harvey, Celia Fukes, Behnam Taghinejad, Jillian Mackay and MN Wesley each solved issue 287's puzzle and receive a copy of *Wildlife Of The World* (Dorling Kindersley, £35).



## WIN! 1,234 QI FACTS TO LEAVE YOU SPEECHLESS

The first five correct solutions drawn will each win a copy of *1,234 QI Facts To Leave You Speechless* (Faber & Faber £10.99). Entries must be received by 5pm on 4 February 2016. See below for more details.



## YOUR DETAILS

NAME

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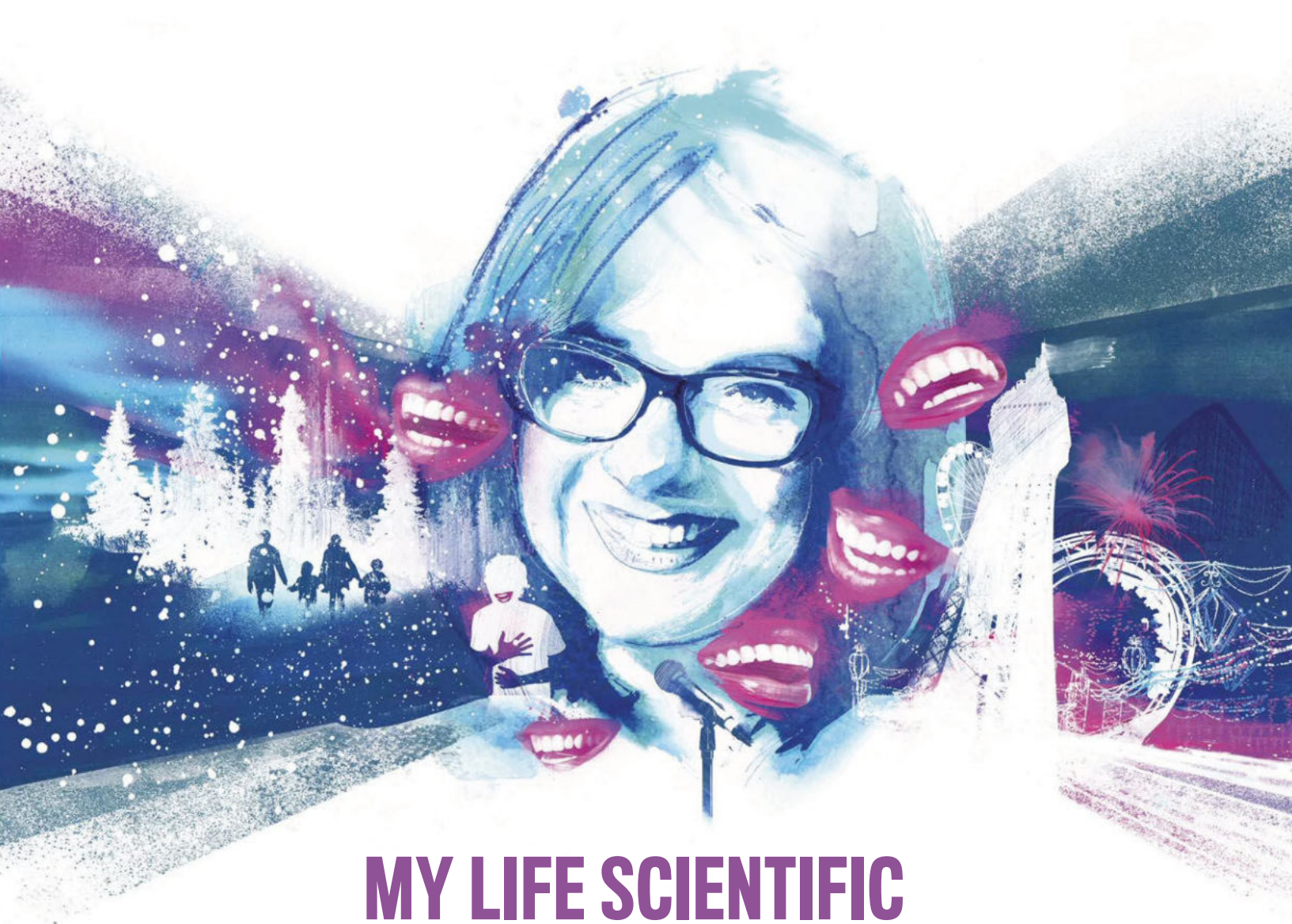
Post entries to *BBC Focus Magazine*, January 2016 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to [january2016@focuscomps.co.uk](mailto:january2016@focuscomps.co.uk) by 5pm on 4 February 2016. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

## TERMS & CONDITIONS

Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. Entries received after the closing date will not be considered. Immediate Media (publisher of *BBC Focus Magazine*) will only ever use personal details for the purposes of administering this competition unless you permit

otherwise. Read more about the Immediate Privacy Policy at [www.immediatemediaco.uk/privacy-policy](http://www.immediatemediaco.uk/privacy-policy). The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.





# MY LIFE SCIENTIFIC

## SOPHIE SCOTT

Neuroscientist at University College London

**Neuroscience has tended to focus on negative emotions like anger and fear, but I'm interested in positive emotions.** That's why I study laughter.

**Laughter is older than us.** It's an old mammalian behaviour to do with social bonding and play. Humour, on the other hand, has been around for as long as we've had language. We can tell from papyrus scrolls that the Ancient Egyptians made terrible jokes about pharaohs. There's also a Roman joke book.

**I've done stand-up comedy.** It was the only time my father ever said he was proud of me! I've performed at the Bright Club – a stand-up science comedy show – for a few years and I've really enjoyed it. It's made me change how I approach things. I now try to put more comedy into my science talks.

**Exercise is really important to me.** I joined a running group on Facebook and now I run every day. You can upload photos or post descriptions of your run, and those in the group can offer support. It's amazing how uplifting it can be; a virtual group of people that I've never met can get me out and running even on the rainiest of days. It's a use of social media I would never have predicted.

**I'm a bit of a control freak.** I can be unbelievably bossy. But I'm aware of that, so I try to moderate it. I also pick my nails. I'm a bossy picker.

**My favourite place is Blackpool Pleasure Beach.** I grew up in Lancashire but my parents were from the south of England. They thought Blackpool was extremely glamorous, so we used to go and see the illuminations there every year. I now visit with my own family and just adore it. There's nowhere quite like it.

**You know sometimes when you laugh really hard and you double up, and you can't control your movements?** I'd really like to understand why that happens. From an evolutionary perspective, it's incredibly unhelpful, a real physical weakness. You wouldn't want to be a caveman rolling around on the floor in fits when a tiger comes along.

**My favourite joke is:** I can't dance to this. My first husband was killed in a love shack.

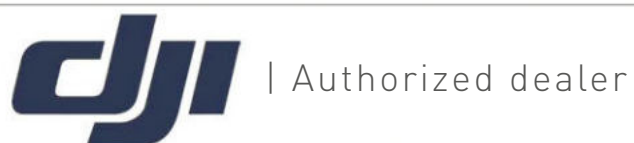
**I'd love to go north of the Arctic Circle to see the Northern Lights.** I'd like to go to Lapland in the middle in the winter when it's all dark and snowy, and take my whole family on an adventure. ■



### DISCOVER MORE!

To listen to an episode of *The Life Scientific* with Sophie Scott, visit [bbc.in/18vrrCf](http://bbc.in/18vrrCf)





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